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Oceanographical and Ecological Studies on Primary Production of the Sea, with Special References to Relationship between Diatom Production and Temperature and Chlorinity of Water

By

Fukuzo Uyeno

Introduction

Among the primary producers in the sea, which build up their organic bodies by assimilating inorganic substances, marine planktonic diatoms are regarded as the most important group because of their vast numbers and ubiquitous distribution. It has been generally considered that the production of diatom population is largely controlled by such environmental conditions as the quantity of inorganic nutrient substances in the water and the intensities of incident solar radiation. At the same time, the production of diatom population which is commonly composed of a number of species may depend upon their preference for environmental factors, of which temperature and chlorinity may be the most significant.

Of the physical or chemical observations on sea water, considerable data on temperature and chlorinity have hitherto been accumulated, and these are now commonly used as the most convenient means for representing the nature of water mass. On the other hand, many biological oceanographers have worked on the population of planktonic diatom as well as distribution of species in connection with the oceanographical conditions of the habitat. They maintain that the occurrence of specific species and the composition of appearing species are highly valuable in indicating the nature of water mass, since, generally speaking, the changes in environmental conditions are sensitively reflected in the planktonic diatoms, whose existence is entirely passive to the water current.

The author has in the early stages studied, in collaboration with his colleagues, the problems mostly dealing with the distribution of marine planktonic diatoms. The areas investigated covered the Kuroshio region, south of Honshu (Matsudaira et al. 1955), the sea off Kinkazan on the north-eastern coast of Honshu (Marumo et al. 1956), the sea off Shionomisaki, south of Honshu (Uyeno 1957a), Osaka Bay (Uyeno 1957b, 1957c, 1957d), the sea off Enshu-nada, south of Honshu (Uyeno 1957f, 1958b), and sea area in the south of Honshu (Uyeno 1957e, 1958a).

The present paper gives a concise summary of these works, including a discus-

sion on the meaning of temperature and chlorinity as the factors controlling the production of diatoms directly or indirectly.

In the next place, on the basis of the observed data on the quantity of diatoms, temperature and chlorinity, an isometric curve (Fig. 13) is drawn to show the quantity of diatoms occurring at any combination of temperature and chlorinity. This graph will be used for the estimation of the diatom productivity at any place in which actual observation on the yearly production of diatoms is lacking. It is hoped that this study will contribute to the development of inshore oyster culture, since such industries depend primarily upon the basic production of the sea. Special attention is focused on several areas on the coasts of Japan where the cultivation of pearl oyster, *Pteria* (*Pinctada*) *martensii* (Dunker), is being carried on or being anticipated.

Finally, range of temperature and chlorinity of twenty-five diatom species which are particularly important in Japanese waters is discussed by using the isometric curves given in Figs. 45–69. This quantitative treatment will give a better idea of the geographical distribution of those diatom species than merely recording the presence or absence of those species in respective temperature and chlorinity.

Acknowledgment

The author was initiated into the plankton study when he was a student at the Tokyo Imperial University under the direction of late Dr. Kenzo Kikuchi, Professor of Zoology at that time, and continued his work, after graduation, at Kobe Marine Observatory under the guidance of Dr. Yasuo Matsudaira Director of that observatory at that time, the present Dean of the Faculty of Fisheries and Animal Husbandry, Hiroshima University. Throughout the later stage of his work on planktonology, he has remembered and sincerely appreciated their kind guidance which gave so much motivation to him in advancing his work. He expresses his sincere thanks to Dr. Yaichiro Okada, Dean of the Faculty of Fisheries, Prefectural University of Mie, for the kind encouragement given to him since the day of his appointment to the present post in 1958. He is also greatly obliged to Dr. Tetsuo Inukai, Professor of Zoology in the Faculty of Agriculture, Hokkaido University and thanks to the helpful criticism of the Professor, he was able to finish this paper. He is also deeply indebted to Dr. Sueo M. Shno, Professor of Zoology in the Faculty of Fisheries, Prefectural University of Mie, to Dr. Takashi Tagawa, Professor of Botony in the Faculty of Agriculture, Hokkaido University, and to Dr. Shigeru Motoda, Professor of Marine Biology in the Faculty of Fisheries of the same university, for their kindness in doing tedious work to read over the manuscript. His thanks are also due to numbers of other persons who have kindly helped him throughout the course of this study.

I. Influence of temperature and chlorinity and movement of water on total quantity of diatoms and composition of species

Referring to the data obtained by himself, the author here presents several examples which show how intimately the horizontal distribution of diatoms is connected with the change of temperature and chlorinity of water and how their horizontal and vertical distributions are disturved by the mixing of water.

1. Quantitative occurrence of diatom communities and horizontal distribution of temperature-chlorinity in Osaka Bay

Results of observations made in Osaka Bay during the months from June to October through four years from 1952 to 1955 (Uyeno 1957b, 1957c, 1957d) gave an example of fair relationship between diatom abundance and temperature-chlorinity. The diatom populations were divisible into the following five communities according to the time of their occurrence and the location of their concentrating regions.

1. *Skeletonema* community, mainly composed of *Skeletonema costatum.*
2. *Chaetoceros* community, mainly composed of *Chaetoceros affinis*, *C. compressus*, *C. curvisetus*, *C. decipiens*, *C. didymus*, *C. distans*, *Bacteriastrum varians* and *Thalassiothrix frauenfeldii.*
3. *Nitzschia-Leptocylindrus-Thalassionema* community, mainly composed of *Nitzschia delicatissima*, *N. seriata*, *Leptocylindrus danicus*, and *Thalassionema nitzschioides.*
4. *Lauderia-Guinardia-Thalassiosira* community, mainly composed of *Lauderia borealis*, *Guinardia flaccica* and *Thalassiosira nordenskiöldii.*
5. *Coscinodiscus* community, mainly composed of *Coscinodiscus radiatus*, *C. marginatus*, *C. gigas*, *Rhizosolenia* spp. and *Biddulphia sinensis.*

During the period from June to September when chlorinity was decreasing, the cell number of *Skeletonema* community was increasing. On the other hand, during the period from September to October when chlorinity was increased, the cell number was decreased. There was a time lag between the increase of cell number and the decrease of chlorinity of the water. In this community apparent increase of cell number was observed about two weeks after the appearance of low chlorinity which occurred as a result of a heavy rain. Growth of *Nitzschia-Leptocylindrus-Thalassionema* community showed a similar negative correlation with chlorinity of the water, and the time lag in the increase of cell numbers was somewhat larger than in the case of *Skeletonema* community, being about three weeks. The growth of *Chaetoceros* community had apparently an intimate correlation with the rise of water temperature. There was also a certain positive correlation between the growth of this community and the fall of chlorinity of the water; the propagation was accelerated by a low chlorinity to a certain extent in this community.

Lauderia-Guinardia-Thalassiosira community showed a tendency similar to that of *Chaetoceros* group. The maximal growth of this community, however, usually occurred when *Chaetoceros* community was declining. This possibly resulted from the preference of this community for a relatively lower temperature than the *Chae-*

toceros community. *Coscinodiscus* community, which consisted of immigrants from offshore water, made their appearance in a large quantity when the chlorinity of the bay water rose.

In the area now in question, the range of chlorinities in which each diatom community was most productive was as follows:

Skeletonema community:	14.0–15.0 Cl ‰
Nitzschia-Leptocylindrus-Thalassionema community:	15.0–16.0 Cl ‰
Chaetoceros community:	16.5–17.0 Cl ‰
Lauderia-Guinardia-Thalassiosira community:	16.0–17.0 Cl ‰
Coscinodiscus community:	more than 17.0 Cl ‰

Schematic explanation of distribution of diatom communities according to the changes of chlorinity is shown in Fig. 1. At times, it happened that the area in which diatom population was most abundant deviated from the area with the optimum range of chlorinity indicated above. This arose from the presence of a current circulating in the bay, which tended to force the distribution of diatoms to move from the area of optimum chlorinity eastward, especially at the period of the decline of their growth (Uyeno 1957d). Thus, diatom production in Osaka Bay was closely related to the change of temperature or chlorinity, although it was influenced slightly by the current also.

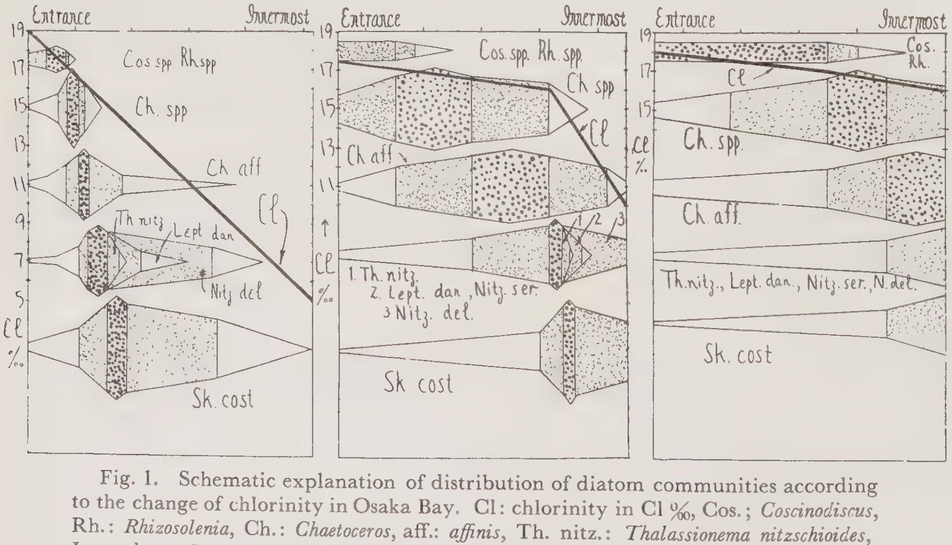

Fig. 1. Schematic explanation of distribution of diatom communities according to the change of chlorinity in Osaka Bay. Cl: chlorinity in Cl ‰, Cos.; *Coscinodiscus*, Rh.: *Rhizosolenia*, Ch.: *Chaetoceros*, aff.: *affinis*, Th. nitz.: *Thalassionema nitzschioides*, Lept. dan.: *Leptocylindrus danicus*, Nitz.: *Nitzschia*, ser.: *seriata*, del.: *delicatissima*, Sk. cost.: *Skeletonema costatum*. (After, Uyeno 1937d)

2. Horizontal distribution of diatoms in the Kuroshio region off Shionomisaki and its relation to the horizontal mixing of water

"Kuroshio" is a great warm current flowing toward northeast along the coast

of the southern part of Japan. The sampling of plankton diatoms was made in the region traversing this current from the inshore off Shionomisaki, Central Honshu, to the offshore. The observation were made in all seasons of the years from 1953 to 1955 except the winter of 1954 and 1955 (Uyeno 1957a). The population of diatoms observed in this area during those years comprised the following species:

Bacteriastrum elongatum
B. comosum
B. varians
Chaetoceros atlanticus v. *neapolitana*
C. dadayii
C. eibenii
C. pendulus
C. peruvianus
C. affinis
C. affinis v. *willei*
C. brevis
C. compressus
C. curvisetus
C. decipiens
C. distans
C. diversus
C. lorenzianus
C. messanensis
Cerataulina bergonii
Clymacodium frauenfeldianum
Corethron hystrix
Coscinodiscus excentricus
Dactyliosolen mediterraneus
Ditylum brightwellii
Guinardia flaccida
Eucampia cornuta
E. zoodiacus
Hemiaulus hauckii
Leptocylindrus danicus
Nitzschia closterium
N. delicatissima
N. seriata
Rhizosolenia bergonii
R. alata f. *graccilima*
R. calcar avis
R. delicatula
R. setigera

R. stolterfothii
R. styliformis
Skeletonema costatum
Thalassionema nitzschioides

The samples contained a great variety of the species, but the composition of species was substantially the same throughout the sampling stations; the distance

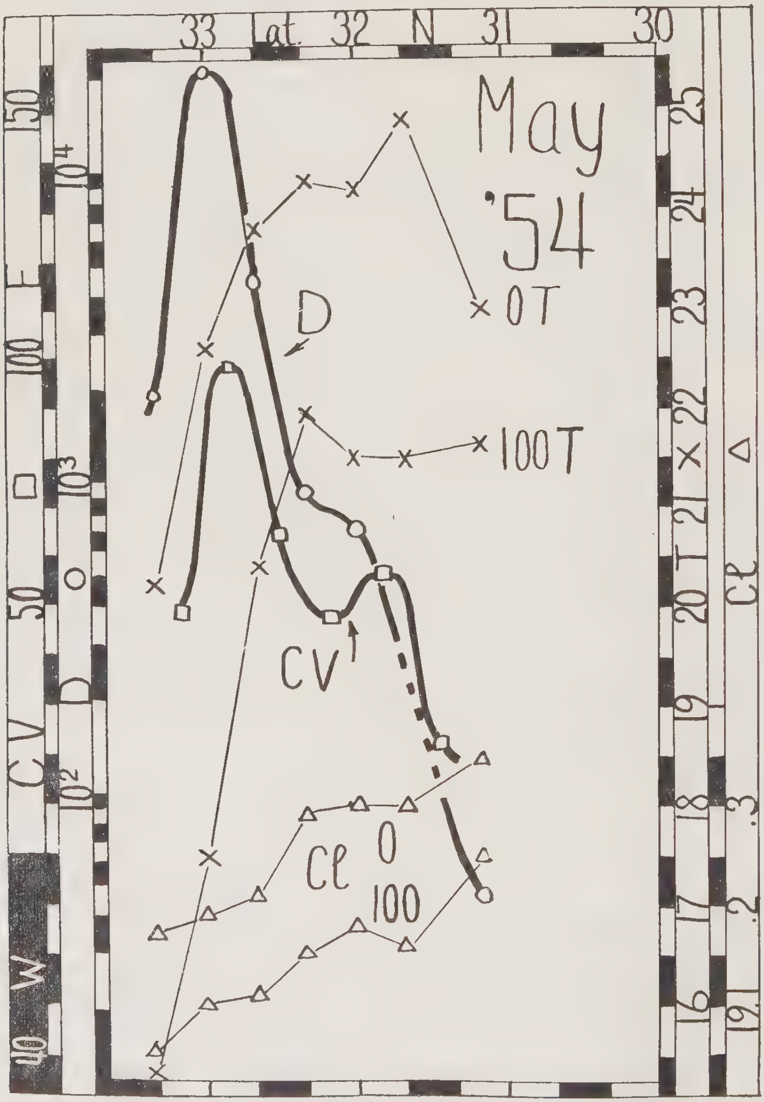

Fig. 2. Changes of total cell number of diatoms (cells/L), current velocity (surface, cm/sec), water temperature (0, 100 m layers, °C) and chlorinity (0, 100 m layers, Cl ‰) in May 1954 in the sea south off Shionomisaki. D: diatom quantity, C. V.: current velocity, Cl: chlorinity. (After, Uyeno 1957f)

of the locality from the coast made no difference. There was no apparent indication that the composition of species could be effectively used for dividing the Kuroshio region into several distinct areas. The total quantity of diatoms varied with the locality of samplings. It was found that the northern peripherical zone of the current contained the largest quantity of diatoms and warm core, the zone near the southern periphery of the current, had the smallest amount. From the northern periphery to the southern periphery, the quantity of diatoms gradually decreased. In the case where the Kuroshio was divided into two streams, the zone interposed between the two streams showed a uniform quantity of diatoms, not showing a gradual decrease from the inshore to offshore area as in the case of the Kuroshio having a single stream. This zone corresponded to the region of the stagnant water. The gradient of diatom quantity from inshore to offshore reversely corresponded to the gradient of temperature as well as of chlorinity. Thus in spite of the fact that the composition of species did not apparently vary with the places from which the samples were taken, the quantity of the total population decreased in proportion to the increase in the mixing of water until it reaches the minimum on the offshore side of the Kuroshio. The area broading on the zone with the largest quantity of diatoms and by that with the smallest quantity represented the breadth of the Kuroshio. Changes of total cell number of diatoms, current velocity, water temperature and chlorinity in May, 1954 is shown in fig. 2. In the farther offing along the outer periphery of the current there is a narrow zone occupied by certain species, such as, for example, *Chaetoceros distans*. The flora involving this species in this zone supposedly has its origin in Hyuganada which is situated far westward. On the offshore side of the zone some tropical oceanic diatoms make their appearance, though they comprise only a small number of species.

3. Influence of vertical mixing of water upon vertical distribution of diatoms in cold water region off Enshu-nada

The discussion given in this section is based on the results of observations carried out in the offshore region of Enshu-nada, south of Honshu. These observations were made once in 1955 from August to September and four times in 1956 (Uyeno 1957e, 1958b). The area is very interesting because of the frequent upwelling of deep water, around which the eastward flowing Kuroshio is forced to take a round about route toward the south. In May and August 1956 the upwelling of deep water did not occur as may be seen from the figures showing the vertical distribution of temperature (Fig. 3) and that of chlorinity. In that year the northern (inshore side) periphery of the Kuroshio was more densely populated with diatoms, for instance with *Chaetoceros compressus* (Fig. 4). Their abundance did not decrease until depth of about 300 meters. It is considered that the diatoms distributed below the euphotic zone (the compensation depth supposedly lay 50–100 meter deep according to the data on submarine light put forward by Sasaki, Oshiba and Okami

(1957)) originate from those which have sunk from overlying zone after the loss of their activity. In August 1955 and in March (Fig. 5) and November 1956 the upwelling of cold water was found to extend over a considerably larger area. In those cases, both northern and southern borders of the cold water region contained a denser population of diatoms than in any other region. The two vertical condensations were connected with each other by a subsurface zone which was limited by the isothermal lines of 12° and 14°C. No diatom, however, was found at the center of the upwelling. This state of things may be illustrated well by the instance of *Nitzschia delicatissima* (Fig. 6). Such a pattern of diatom distribution as observable in this area suggests that the denser population on the peripheries of the cold water region has resulted from the convergence of water and that the nearly complete absence of

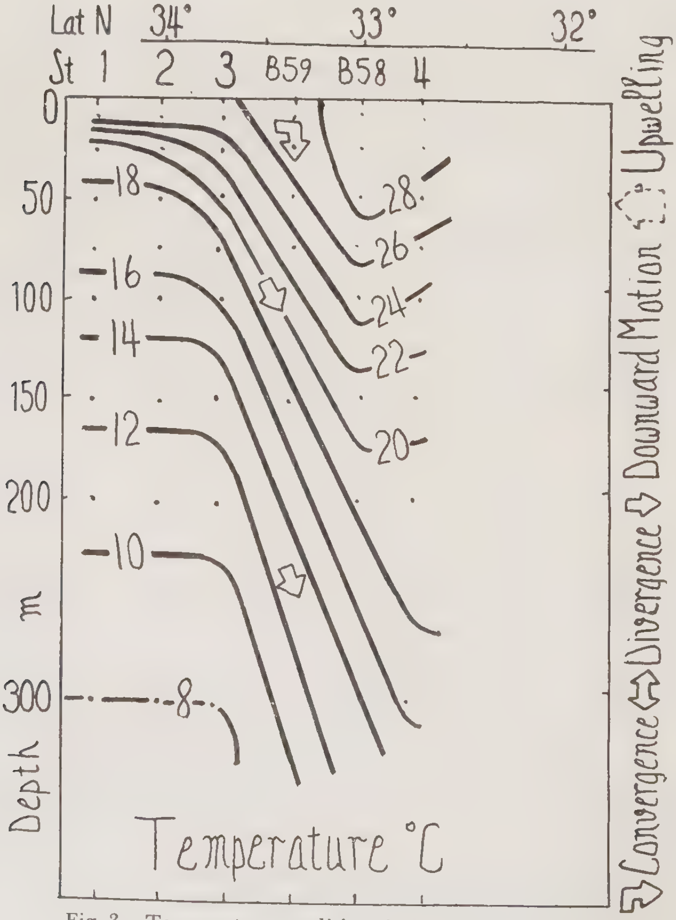

Fig. 3. Temperature conditions in a vertical section off Enshu-nada, in Aug. 1956. (After, Uyeno 1957f)

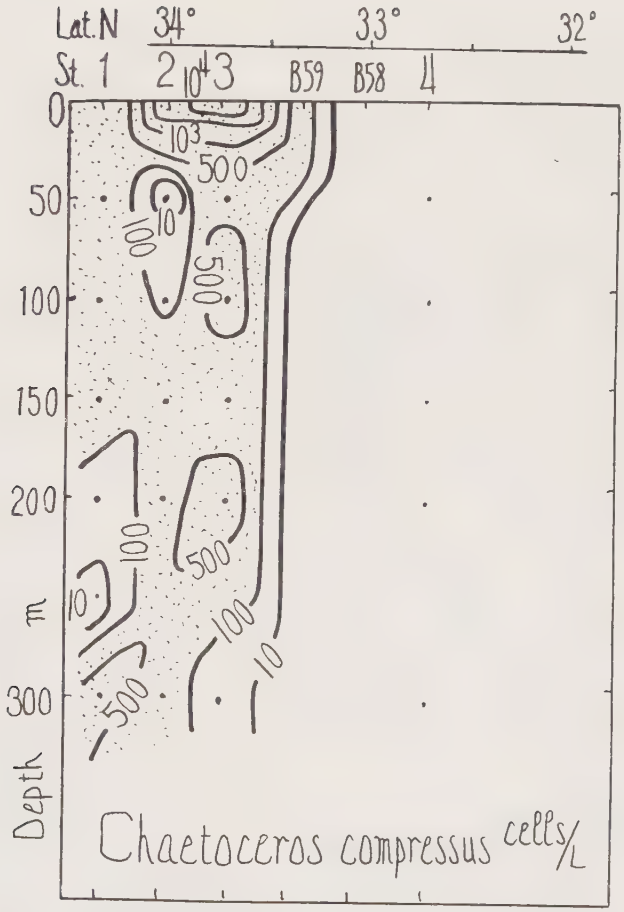

Fig. 4. Abundance of *Chaetoceros compressus* in a vertical section off Enshu-nada, in Aug. 1956 (cells/L). (After, Uyeno 1957f)

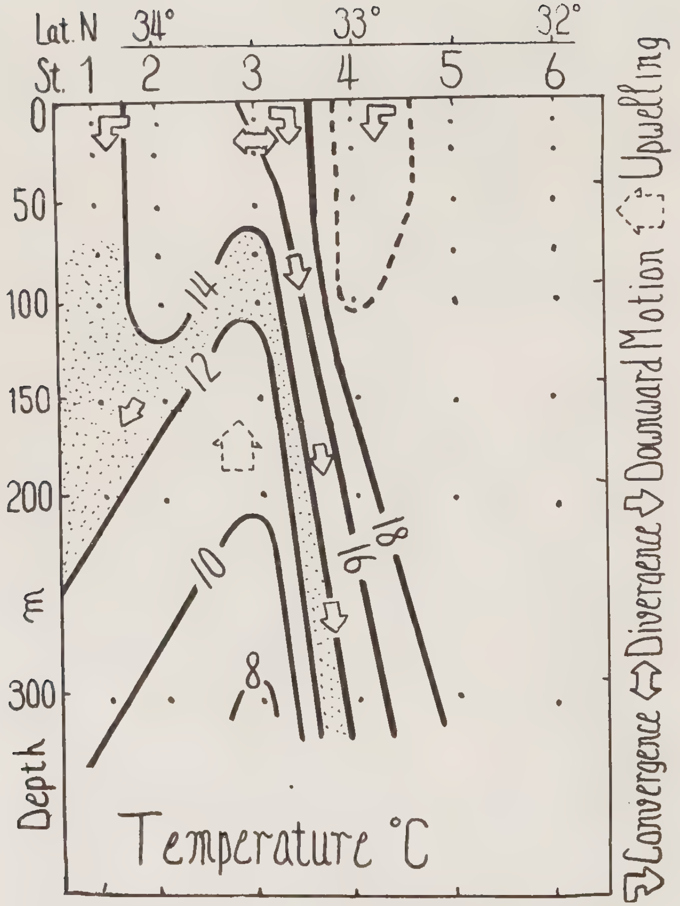

Fig. 5. Temperature conditions in Mar. 1956 in the same area as in Fig. 3. (After, Uyeno 1957f)

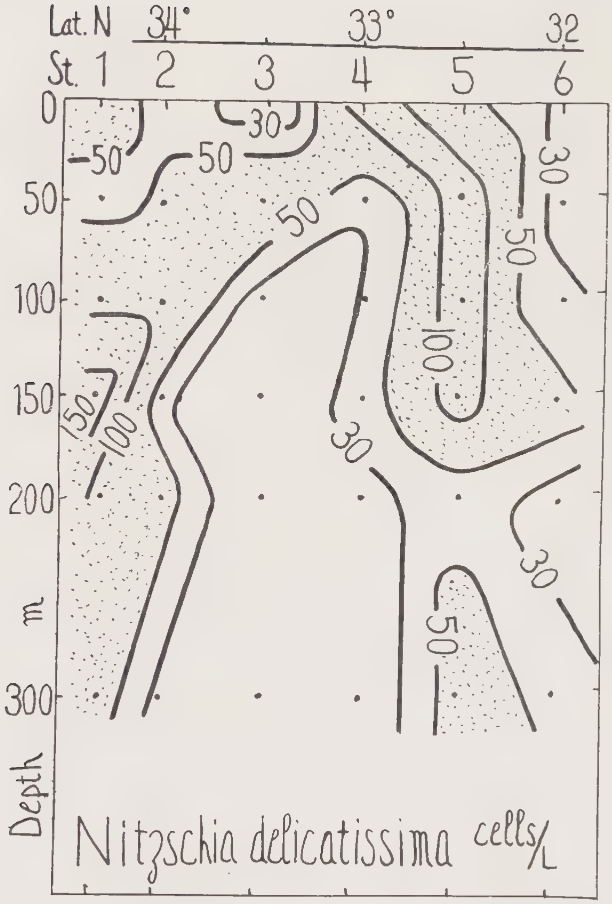

Fig. 6. Abundance of *Nitzschia delicatissima* in Mar. 1956 (cells/L), in the same area as in Fig. 5. (After, Uyeno 1957f)

diatoms on the surface of the region where the cold upwelling water occurs has been effected by the divergence of water. The diatoms were carried vertically downward in the region where the isotherms ran horizontally, while they were forced to move along the isotherms in the region where the isotherms showed an inclination in relation to the sea surface. In the latter case, the presence of a downward movement of water along the isotherms was presumed. Thus, the vertical movement of water in this area fairly reflected on the distribution pattern of diatoms, irrespective of presence or absence of cold water.

II. Proposal of a method of analyzing the quantitative distribution of diatoms in relation to temperature and chlorinity

A proper understanding of the relation between the distribution of diatoms and the temperature-chlorinity factors will not be obtained by a qualitative analysis, but also by the quantitative analysis of the data on the diatoms and those on temperature and chlorinity at the place of sampling.

Data available for such an analysis were derived from three series of observations carried out by Kobe Marine Observatory (1955–1958) and from those by the Cooperative Plankton Research under the direction of Kokubo (1931–1940). The former series consisted of 22 regular monthly observations in Osaka Bay covering the period from January 1954 to November 1955, five observations in the Kii Channel from May to December in 1953 and eight observations off the south of Honshu from March 1955 to November 1956 (Fig. 7). The samples obtained amounted to 649 vials in all. They were gathered from the water dipped up from the surface of the sea and were concentrated by decanting and centrifuging. Each dip was 100 cc in quantity in the case of Osaka Bay and the Kii Channel, but 500 cc in the sea south off Honshu. Identification of species and enumeration of cell numbers were made personally by the author, so that no personal error might be involved in the measurements.

In the Cooperative Plankton Research which was aimed to obtained the knowledge on the quantitative distribution of diatoms in various localties as accurate as possible by the use of the standardized method, the data were published in "Plankton Journal" (Plankton Jiho) (Kokubo 1931–1940). The observations were made at intervals of a half month during the years from 1930 to 1933 at twelve stations around Japan covering the coasts of South Saghalien, Japan Islands, South Korea and Formosa (Fig. 7). In every case, water of ten liters was dipped up from the surface and poured into the settling bottle of special make with a capacity of ten liters, in which the floating matter was made to precipitate and concentrate (Kokubo 1931–1940). Examination of the samples, 420 vials in total, was mostly done by Dr. Kokubo and his colleagues, although certain parts of them were left to others.

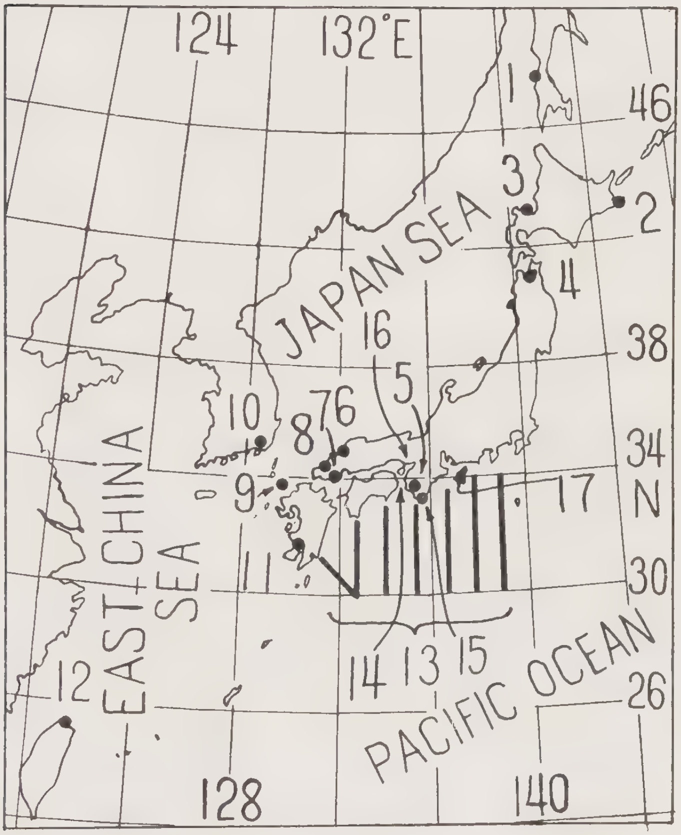

Fig. 7. Stations of observations: Stations listed in the "Plankton Journal" (1–12) are shown by small black circles. Collections by Kobe Marine Observatory (13–17) were made at the spots arranged in rows which are indicated by thick lines. 1: Rakuma, 2: Nemuro, 3: Takashima and Yoichi, 4: Asamushi, 5: Kanayama, 6: Hamada, 7: Mitajiri, 8: Senjima, 9: Kakarajima, 10: Pusan, 11: Kagoshima, 12: Sharyoto, 13: Tows of the spots of observation in the sea south of Honshu, 14: the Kii Channel, 15: Cape Shionomisaki, 16: Osaka Bay, 17: Enshu-nada.

Chlorinities annexed to the data on plankton sampling were obtained by the titration method in the case of the observations by Kobe Marine Observatory, while those in the Cooperative Plankton Research were obtained by the conversion from the specific gravity read on the hydrometer. In the latter case, therefore, a certain degree of inaccuracy might have accompanied the numerical values.

Figs. 8 and 9 inserted here illustrate the isometric curves showing the distribution of total diatom quantity in relation to temperature and chlorinity. In them the temperature is taken in equidistant scale on the ordinate and the chlorinity in negative logarithmic one on the abscissa (c. f. Uyeno 1958d, 1959). The total cell number of diatoms in each population is plotted on the diagram against the tem-

perature and the chlorinity obtained at the place of sampling. For each of the spaces enclosed by the graduation of temperature (ordinate) and of chlorinity (abscissa) in the diagrams (Figs. 8 and 9), the mean of the cell number which is expressed by the logarithm of the geometric mean of actual cell number per 10 liters of water has been calculated. In this calculation the data from Kobe Marine Oservatory (1955–1958) and from Kokubo (1931–1940) have been separately treated, those from the former being indicated in Fig. 8 and those from the latter in Fig. 9. The isometric curves connecting equal mean values have been drawn in the diagrams.

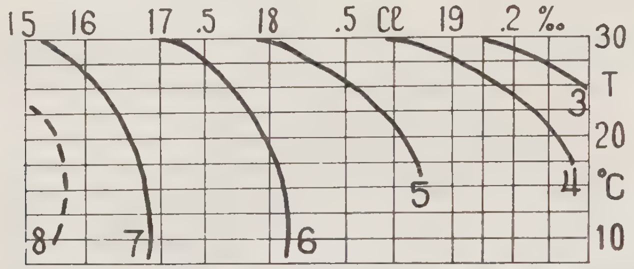

Fig. 8. Isometric curves showing the change in the total cell number of all the appearing species represented by logarithm of cells per 10 L. Based on the data published by Kobe Marine Observatory (1955–1958). T, temperature; Cl, chlorinity. (After, Uyeno 1958a)

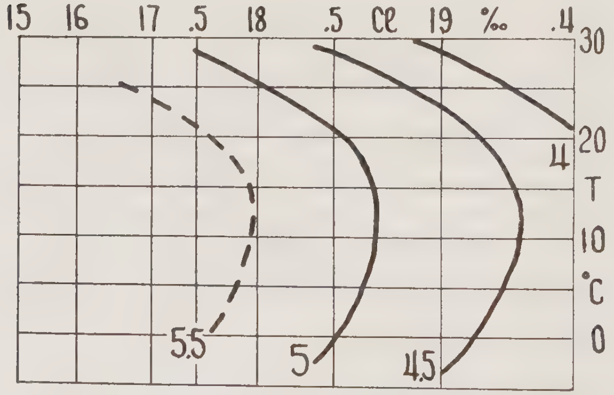

Fig. 9. Isometric curves showing the change in the total cell number of all the appearing species represented by logarithm of cells per 10 L. Based on Kokubo's data (1931–1940). Abbreviations as in Fig. 8. (After, Uyeno 1958d)

Those figures indicate that the temperature factor has not so large an influence on the diatom quantity. When the temperature in high the reduction of cell number becomes particularly apparent at 25°C or more. The chlorinity factor, on the contrary, exerts a large effect when the temperature is not very high. Every isometric curve which turns toward the right in low temperature turns toward the left (toward lower chlorinity) about from 15°C upward. This means that most of the species

involved in the collections have their optimum temperature at about 15°C. The total cell number of all diatoms which should occur at any combination of temperature and chlorinity will be perceivable from those diagrams. If temperature and chlorinity are known, therefore, the number of diatom cells occurring at any locality may easily be calculable.

It is interesting to compare the result obtained by this method with that calculated by the metabolic rate of organisms and the effect of environmental conditions (Riley and von Arx 1949).

Riley and von Arx (1949) proposed the following theoretical formula for calculatiug the productiou of phytoplankton:

$$Pt = Po\ e^{(Ph-R-G)t}$$

where *Po* represents initial population, *Pt* final population, *Ph* photosynthetic rate, *R* respiratory rate and *G* grazing rate by herbivores. According to them, the photosynthetic rate is closely related to the incident solar radiation, depth of euphotic zone, vertical turbulence of water and depletion of nutrient. The respiratory rate varies with temperature, and grazing rate varies with the number of herbivores and their activity. By adopting this theory Riley and von Arx (1949) calculated the seasonal fluctuation of phytoplankton production in Husan Harbor (Fig. 10). Another curve obtaind by the method proposed in the present study and also one based on the observed cell number (Kokubo 1931–1940) are drawn in the same figure. It is noteworthy that these are almost coincident with one another except for the discrepancies perceivable in July 1932 and May 1933 when the chlorinity was greatly reduced

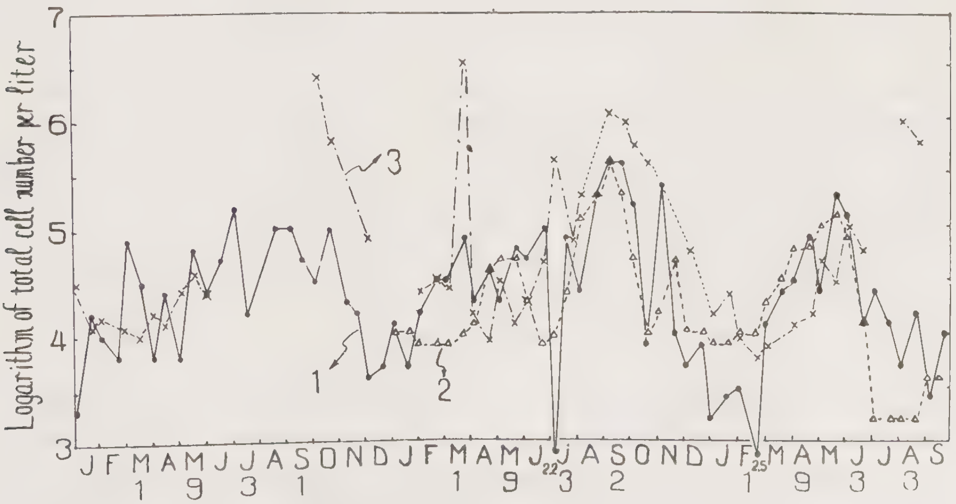

Fig. 10. Seasonal variation of diatoms in Husan Harbor. 1: variation of cell number based on actual observations (Kokubo 1931–1940). 2: theoretical curve drawn after Riley and von Arx's formula (1949). 3: curve drawn after the author's method. (After, Uyeno 1958c)

on accout of land drainage. A sudden fall of chlorinity seems to be unfavorable to the growth of diatoms and results in the decline in cell number. A return to normal restores the active growth of diatoms occurs, by which the population reaches the maximum of the year. The curve drawn after the method proposed here shows that the diatoms were abundant in July 1932 and May 1933, differing from the curve based on the actual observation. This discrepancy appears to be due to the time lag between the growth of diatoms and the change of environment. In winter, the retardation of cell division in diatoms may becomes more apparent than in any other seasons, so that the disagreement of the curves also becomes distinct in that season. This is the case not only with the curve constructed by the author, but also with RILEY and VON ARX's theoretical one (UYENO, 1958d).

III. Temperature and chlorinity as ecological factors playing a rôle in the cycle of production in the seas

As stated in the introduction, the aim of this study is to explain the relationship between diatom distribution and temperature-chlorinity factors. In other words, it is to demonstrate the validity of the quantitative distribution of diatoms as an indicator of water mass which is normally identified by temperature and chlorinity. The temperature and chlorinity may not have any direct effect upon the production of organisms, (although temperature may have a certain effect upon the metabolism of organisms), as for instance in such conditions as solar radiation or nutrient substances. However, if the quantitative distribution of diatoms is representing the nature of water mass, it is natural that temperature-chlorinity factors are certainly correlated with the entire process of the production.

RILEY and his colleagues, who made the theoretical studies on the production in the sea, attempted to analyse the production of phytoplankton, on the basis of photosynthesis, respiration and grazing in various sea area, such as Georges Bank (RILEY 1946), New England coastal waters (RILEY 1947), Husan Harbor (RILEY and VON ARX 1949), western North Atlantic (RILEY, STOMMEL and BUMPUS 1949) and Long Island Sound (RILEY et al. 1956). Similar analysis has also been made by many others. CUSHING (1955) proposed a formula for representing the process of the production in the sea.

$$P = Po\ e^{(R-M-K)t}$$

where P is the number of diatoms occurring after the lapse of time t, Po is their initial number, R is the daily division rate of them, M is the daily natural mortality rate of them and K is the daily herbivore grazing rate on the diatom species. He deduced the division rate of diatoms from the thickness of frustules, which may become thinner with each division, and the natural mortality rate from the presence or absence of chlomatophores within the cell. He (1955) proposed, at the same time,

another method of estimating the production which is based on the magnitude of intake of phosphate by the cells. The fact reported by PRATT (1950) and EDMONDSON (1955), that there is a constant correlation between phosphate regeneration and chlorophyll concentration, proves the usefulness of CUSHING's method for the present purpose. ARMSTRONG and HARVEY (1950) pointed out that the ratio between organic and inorganic phosphorus in the sea is not constant, but varies according to the season. He explained that this is due to the intake of inorganic phosphorus by phytoplankton and liberation by their decomposition. EDMONDSON (1955) also mentioned that the particulate phosphorus in the sea water increases when inorganic phosphorus is taken in by phytoplankton.

Although these works dealt with various factors which bear some relation to the primary production in the sea, there has been no attempt to disclose the relationship between the production and chlorinity. RILEY and VON ARX (1949) were the only authors who in their studies on the production system in the sea took into consideration the chlorinity of water as a factor of vertical turbulence. MATSUE (1954) carried on an experiment on the relation between the growth rate of *Skeletonema costatum* and the chlorinity of culture media and found that the species was capable of growth in the range of chlorinity from 7.1 to 27.7 Cl ‰ and grew most rapidly at 13.3–19.9 Cl ‰. The present author (1957 c), in his observation in Osaka Bay, found the highest concentration of the species in the area of 14.0–15.0 Cl ‰. The most favorable range of chlorinity was thus somewhat narrower than that obtained by MATSUE (1954).

It was pointed out before, that the temperature and the chlorinity are the important factors controlling the primary production in the sea, even if their effect is indirect. Taking the factors of temperature and chlorinity into consideration, the author proposes here diagrams showing the whole cycle of organic production in the sea.

Phosphate, inorganic nitrogen compounds, probably silicate and other rare elements, or enzymes, of which little is known, constitute the important factors in the production of diatoms, controlling, in extreme cases, their growth. In the phosphorus cycle in the sea the major portion of organic phosphorus compounds results from the plant tissues. The organic phosphorus are decomposed by the action of phosphatase within the cells to become orthophosphate after the death (MATSUE 1949). A similar process occurs also in the decomposition of faecal pellets and the dead bodies of animals. The remineralization of the organic phosphorus usually takes place very rapidly and the whole of the phosphorus cycle is, accordingly, almost completely confined in the euphotic zone. Tissue particles of plants and animals are either eaten by other animals, or are disintegrated by the action of bacteria (HARVEY 1955). Although to some degree the organic phosphorus may be lost from euphotic zone due to their descent toward the deep, the loss will be compensated for by those brought in with the inflow of rivers (HARVEY 1955), or by those transported from the deep water by some mechanical agencies (REDFIELD, SMITH and KETCHUM

1937).

In the nitrogen cycle, on the other hand, the organic compounds are so sluggish in their process of decomposition, for which the action of bacteria is indispensable, that they are carried away for the greater part to the deeper water as suspending matter. In the euphotic zone, the recovery of inorganic nitrogen compounds to be effected by the decomposition of the organic compounds is very small. Thus, the nitrogen is usually more highly concentrated in the deep than phosphorus is. Concerning the supply from the land water, Harvey (1955) said that "The annual addition to the sea from land drainage is considerable, but compared with the store of combined nitrogen in sea water this addition must be very small indeed". However, most of the addition from land drainage may be directly supplied to the euphotic zone. With respect to the inorganic nitrogen which diatoms demand, two of the supply sources can be assumed, one being derived from land water and the other from deep water. It is a question which of the two has a larger concern. In neritic waters, especially in that of temperate or tropical region, the supply from land drainage may be larger than that from deep water, for in those regions diatoms are

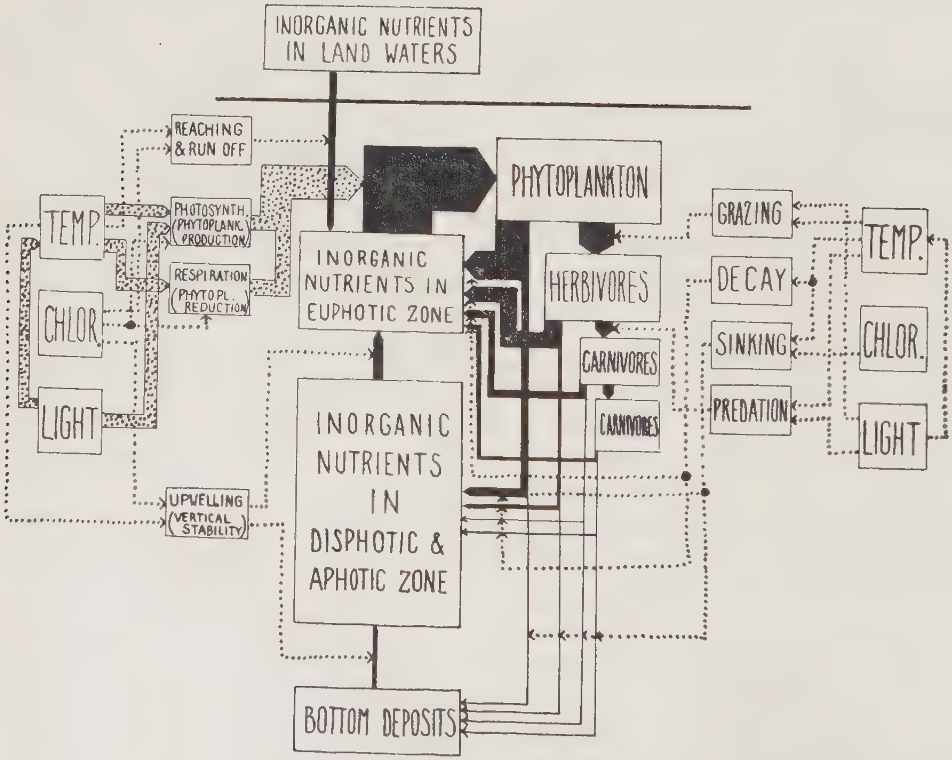

Fig. 11. Diagramatic representation of phosphorus cycle in the sea with special reference to temperature and chlorinity. Ordinary lines indicates to the course of cycle and dotted ones the action of environment. Width of the arrow represents the magnitude.

more abundantly distributed in the coastal region. In relatively colder waters where the vertical mixing of water occurs to a considerable extent, the supply from deep zone to the euphotic zone will be important.

Figs. 11 and 12 illustrate the phosphorus and nitrogen cycles in the sea. In the figures, the cycle of substances or organisms are indicated by the lines or by the wide or narrow black arrows, the width of which roughly corresponds to the magnitude of their transference from one to the other. The influence of one item to the other in the physico-chemical and biological environments is represented by the dotted line or arrow and the degree of the action by the width of the arrow. The term "decay" used in the figure implies all the processes of remineralization including bacterial, enzymatic and catalytic actions against tissue particles of corpse, or against faecal pellets. "Sinking" means the same in all cases, whether used for organisms or for suspending matters derived from the former.

As seen in Fig. 9, the rate of consumption of phosphorus will be affected by the temperature. Needless to say, light is the most important factor, which together with temperature controls the essential part of photosynthesis. The solar energy has a great effect on the water temperature. Both grazing and predation are

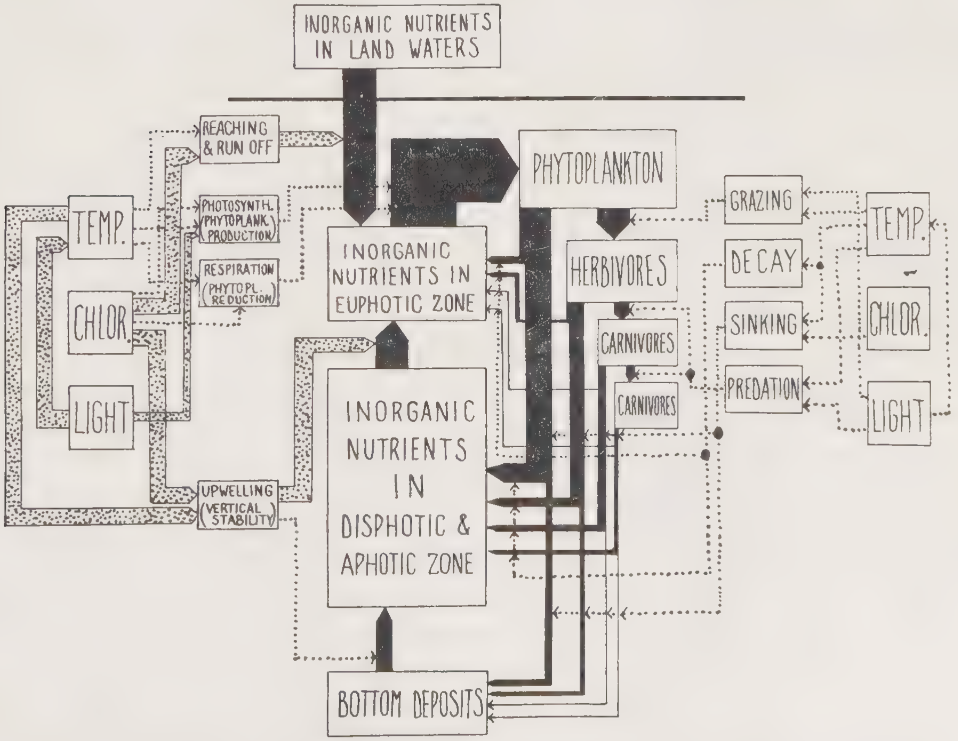

Fig. 12. Diagramatic representation of nitrogen cycle in the sea with special reference to temperature and chlorinity. Ordinary lines indicate the course of cycle and dotted ones the action of environment. Width of the arrow represents the magnitude.

biological in their function, which proceed under the influence of water temperature. Remineralization occurring in the phosphorus cycle takes place immediately after the organic phosphorus are isolated from the cells of organisms (Harvey, 1955). Since the main course of phosphorus circulation is confined within the euphotic zone, the rapidity of the circulation appears to be mainly dependent on the rate of utilization of phosphorus by phytoplankton. This implies that land drainage, or upwelling of deep water is not essential to the phosphorus supply. Accordingly, the circulation is subject principally to water temperature, but very little to chlorinity which is concerned with the land drainage or the upwelling.

Nitrogen circulation, on the contrast to the phosphorus compounds, extends in its main course from disphotic to aphotic zones, and requires a much longer time to complete the cycle than in the case of phosphorus. The increase of phytoplankton is favorably affected by the nitrogen supply either from land drainage, or from deeper sea water. Where land drainage is involved the rate of increase is proportional to the decrease of chlorinity, and where the upwelling of the deep water is involved, it is in proportion to the rate of vertical mixing.

In conclusion, although all of the factors involved in the production of diatoms including phosphorus and nitrogen can not be represented by the function of temperature, or chlorinity, or the combination of both, temperature and chlorinity will bear some indirect relationship to other environmental factors, and consequently serve to control the production of diatoms.

IV. Estimation of productivity based on temperature and chlorinity on the coast of Japan

As mentioned in chapter II, the isometric curves illustrating the change of diatom quantity according to various combinations of temperature and chlorinity resemble an onion in their shape. All isometric curves would become parallel, if a normal scale were used. Differences in their curvature arise from the fact that the chlorinity is represented by antilogarithmic scale.

Now let us consider the annual change of diatom quantity in relation to the temperature and chlorinity. As the first step, the author inserts here a diagram (Fig. 13) which is constructed by combining of Figs. 8 and 9. The second is to plot on this diagram the monthly mean temperature and chlorinity (Figs. 14–19). In Figs. 15–19, the line connecting these points of mean temperature will make a closed curve (black spaces in Fig. 14). This closed curve shows the annual cycle of the cange of temperature and chlorinity. The shape of this curve and the place which it occupies on the graph shows the characteristics of the area. For instance, in the south of Honshu on the zone at 5 to 15 miles' distance from the coast (Fig. 14), the water is 27°–30°C in temperature and 18.6–19.3 Cl ‰ in chlorinity in summer and 15°–22°C and 19.1–19.3Cl ‰ in winter (Kobe Marine Observatory 1955–1956). The zone now in that region consists of two water masses, different from each other in the range of temperature and chlorinity. One of them originates from the sea far

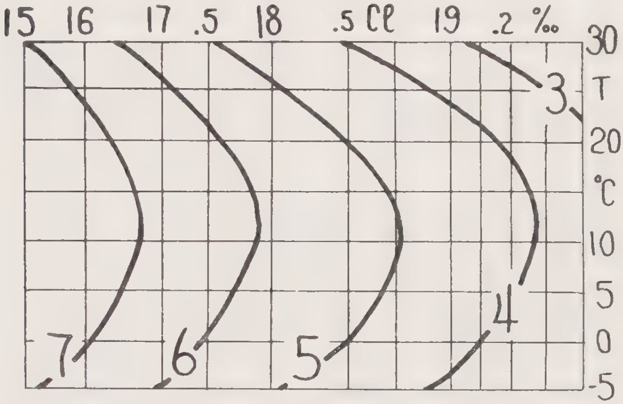

Fig 13. Change in mean diatom cell number for various combinations of temperature and chlorinity in the neighbouring sea of Japan. Numerals attached to the curves represent the logarithmic value of total cell number per 10 liter. (Drawn by the combination of Figs. 8 and 9). T: temperature, Cl: chlorinity.

off the coast and the other from the coastal water (c. f. I–2). On the graph (Fig. 14), the offshore water occupies its position in the immediate neighbourhood of the warmest and the most haline region. In this region, increase in the quantity of diatoms is effected by the fall of temperature rather than by the decrease of chlorinity. The change of temperature and chlorinity occurring from summer until winter produces a remarkable increase in the quantity of diatoms, since the black space showing the fall of temperature during these seasons intersects the isometric curves of diatom quantity, as this may be seen also from Fig. 12–0. In the sea near the coast the black space during the same seasons is almost parallel with the isometric curve representing 10^5 cells/10 L, namely the change of diatom quantity is rather small (Fig. 12–C).

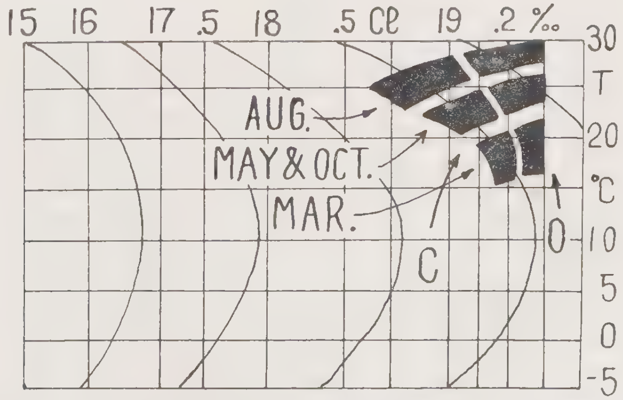

Fig. 14. Annual cycle of temperature and chlorinity with isometric curves of total cell number of diatoms in the sea south of Honshu. O: area far off the coast. C: coastal area. Other abbreviations as in Fig. 13. (After, Uyeno 1958d)

In the central area of Osaka Bay annual change of temperature ranges from 7° to 30°C and that of chlorinity from 13 to 17.5 Cl ‰ (Kobe Marine Observatory 1952–1953). The curve of temperature and chlorinity shows three depressions of chlorinity, respectively in April, July and September (Fig. 15). Diatoms in the bay

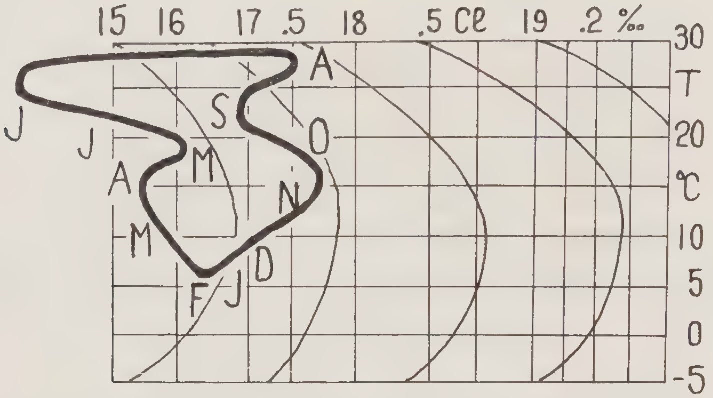

Fig. 15. Annual cycle of temperature and chlorinity with isometric curves of total cell number of diatoms in Osaka Bay. Alphabets attached to the cycle curve represent the initials of the twelve months. Other abbreviations as before. (After, Uyeno 1958d).

are abundant in these months and the best flourish is in July. At Asamushi in Aomori Prefecture (Fig. 16) and at Lightship "Vyl" (Thomsen 1952) in the southern

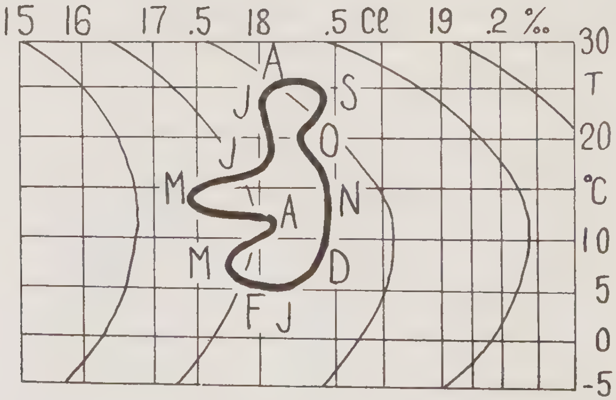

Fig. 16. Annual cycle of temperature and chlorinity at Asamushi. Abbreviations as in Fig. 15. (After, Uyeno 1948d)

part of the North Sea (Fig. 17) the change of diatom quantity is almost parallel with that of chlorinity. This is due to the fact that the cycle curve of the temperature-chlorinity factors is situated near the center of the graph, where the effect of tem-

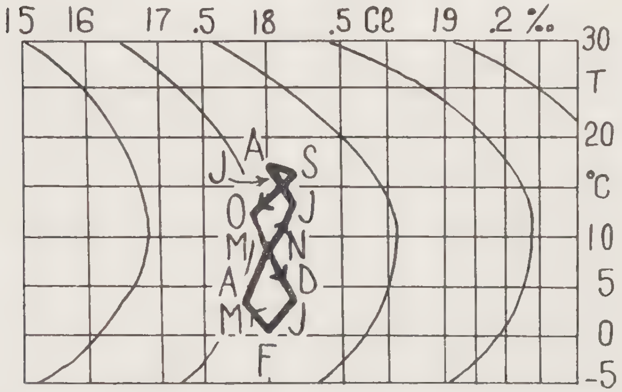

Fig. 17. Annual cycle of temperature and chlorinity in southern part of the North Sea. After the survey by Light ship "Vyl". Abbreviations as in Fig. 15. (After, Uyeno 1958d)

perature on diatom quantity is very slight. Depressions of chlorinity are found in March, May and October at Asamushi and in March and October at "Vyl". Based on the observation in the neighbourhood of the North Sea, GRAN (1931) arrives at the conclusion that everywhere in the world the seasons in which the phytoplankton flourish best are March and October. However, the appearance of the peak in the quantity of diatoms during those months at the above-named stations does not conform to the general rule advanced by GRAN. This is perceivable also from the following examples.

In Iwayama Bay, Palao Island (Fig. 18) the cycle curve of temperature and chlorinity occupies the warmest part of the graph and describes a much depressed ellipse, the longer calibre of which is parallel with the axis of abscissa representing

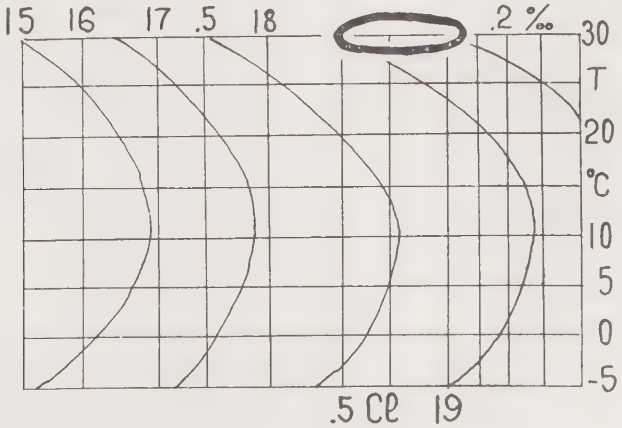

Fig. 18. Annual cycle of temperature and chlorinity in Iwayama. Abbreviations as in Fig. 15. (After, Uyeno 1958d)

chlorinity. The annual climatic condition in the bay is divisible into rainy and dry seasons, throughout both of which the temperature is nearly constant. The rainy season is rich in diatoms, while the dry season is scarce. The annual change in the quantity of diatom in this bay has been formulated by the author into an experimental equation with respect to temperature and chlorinity on the basis of the data put forward by Motoda (1940) (c.f. Uyeno, 1959).

$$\log D = \frac{33-T}{2} + 2 \cdot \log[(20-Cl) \times 100] - 3.5$$

where D is the total cell number per 10 L, T is the temperature of surface water (°C) and Cl is the chlorinity of the same (Cl ‰). The question is based on the assumption that at least within the range of temperature 28.°0–30.°2C and that of chlorinity 18.5–19.0 Cl ‰ all the isometric curves are represented by straight lines parallel with and equally separated from one another. The line representing 0 cell/10 L passes the point corresponding to 33°C and 20 Cl ‰. The result obtained after the above equation and that derived from actual observation of cell numbers (Motoda 1940) are illustrated in Table I.

It is striking that even under such an unusual climatic condition the temperature and chlorinity is very closely connected with the diatom quantity. In colder waters, e.g. Nemuro, Hokkaido (Kokubo 1931–1940) (Fig. 19), Scotch Cap, Alaska (Cupp 1937) and Long Island Sound, North America (Riley et al 1956), the cycle curve of temperature and chlorinity forms an ellipse with its longer diameter parallel with ordinate axis of temperature. That is, the annual fluctuation of temperature

Table I.
Temperature, chlorinity and total cell number of diatoms in Iwayama Bay, Palao from June 1935 to April 1936. (After Motoda 1940)

Month	Aug. 14 1935	Sept. 13	Oct. 5	Oct. 26	Nov. 12	Dec. 31	Feb. 27 1936	Apr. 11	May 21	July 6	Aug. 3
Temperature °C	29.7	28.6	29.2	30.2	29.2	28.6	28.0	29.0	29.8	29.7	29.5
Chlorinity Cl ‰*	18.52	18.50	18.92	18.82	18.81	18.95	19.04	18.89	18.58	18.64	18.04
Total cell number of diatoms (actual) (cells/10L)	1050	550	325	200	400	800	750	650	200	650	2700**
Total cell number of diatoms obtained from T-Cl (cells/10L)	300	800	300	100	400	500	1000	400	250	700	6000

* calculated from specific gravity.
** co-existance of numerous *Nitzschia*

is quite great in contrast to that of chlorinity. The shape of the curve is remarkably characteristic at every station. The disposition of water masses differing with the latitudes are classified into several types, by the shape of the cycle curve. It varies from a depressed ellipse in tropical waters to a compressed one in arctic waters. In the temperate region, the shape is a compound of boreal and tropical

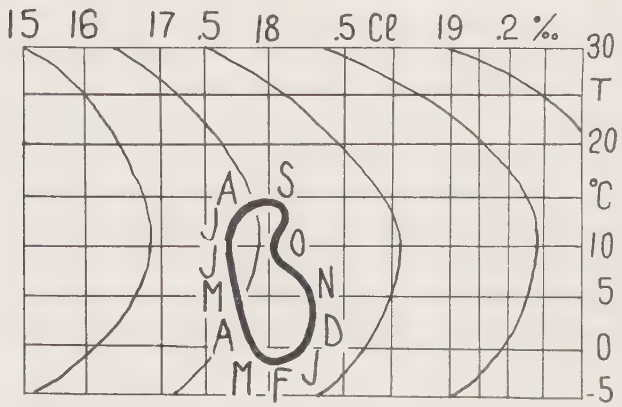

Fig. 19. Annual cycle of temperature and chlorinity at Nemuro. Abbreviations as in Fig. 15. (After, Uyeno 1948d)

types, being tropical in summer and boreal in winter. In conclusion, it may be well to assume that the season in which diatoms are most abundant is determined by the annual change of temperature and chlorinity.

From what has been said heretofore may be concluded that, if temperature and chlorinity are known, productivity of diatoms in a certain area can roughly be estimated. The productivities in various localities of the world has been published by many investigators. Among whom are Cupp (1937) and Motoda (1946) who have given general ideas concerning them. Cupp (1937) has made a comparison of the productivity in Scotch Cap Light with that found in various parts of the world by a number of other workers. She stated that "Diatom productivity at Scotch Cap Light, although by no means poor, was not so great as might be expected from the northerly situation of the station and from reports of large yields in northern Atlantic waters". She concluded, further, that the plankton productivity is not always larger in the higher latitudes than in the lower. Comparing the results of her investigation on the productivity of plankton in Iwayama Bay, Palao with those obtained by a number of other authors including Cupp (1937), Motoda (1946) concluded that the tropical waters are less productive of plankton than the boreal ones. It is true that, compared with the temperate and boreal seas, the tropical seas are generally unproductive. Colder waters, however, can not always be said to be more productive than warmer waters from the results of above studies.

Turning to the open ocean, it is usually barren in comparison with the neritic province at the same latitude as this also has been noticed by numbers of authors for many years. There is very little doubt about this point, since the open ocean is ordinarily more haline than the neritic waters. Accoding to the graph here presented, the sea is most productive when it is about 15°C in temperature and about 15 Cl ‰ in chlorinity. The sea which fulfils such conditions is found in the neritic province of the north temperate zone (Uyeno 1958d).

Following the method proposed above, the author tries here to estimate the

productivity in various localities of the coast of Japan. Data on temperature and chlorinity have been taken from the results of the regular observations made by the Central Meteorological Observatory (1954–1955).

The stations here dealt with are as follows: Nase in Amami Oshima, Uwajima in Ehime, Tadotsu in Kagawa, Owase in Mie, Omaezaki in Shizuoka, Hachijyo-jima in Izu, Tomisaki in Chiba, Onahama in Fukushima, Miyako (Takonohama) in Iwate, Hakodate, Urakawa, Oumu and Esashi in Hokkaido, Aikawa in Sado, Wajima in Noto, Saigo in Oki, Shimonoseki in Yamaguchi, Izuhara in Tsushima, Tomie in Goto and Nagasaki. Changes in temperature and chlorinity at these stations are represented by the monthly averages taken from the observations made during at least seven

Table II
Diatom quantity deduced from mean temperature and chlorinity on the coasts around Japan.

Month	Total cell nuumber of diatoms (log cells/10L)												
	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Nase	4.6	4.9	4.7	4.3	4.5	4.2	4.5	5.5	4.0	4.1	4.7	4.5	4.5
Uwajima	6.4	6.5	6.8	6.8	7.0	7.0	7.3	6.1	6.1	6.1	5.5	6.1	6.4
Tadotsu	6.1	5.9	6.0	5.8	5.8	5.7	5.9	4.9	5.8	6.5	6.7	6.6	5.9
Owase	5.4	5.3	6.3	7.4	7.5	8.0	8.0	7.5	7.5	7.1	6.2	5.8	6.8
Omaezaki	5.0	4.8	4.9	5.2	5.4	5.7	5.7	5.4	5.6	5.9	5.5	5.3	5.4
Hachijyo-jima	3.9	4.0	3.9	3.8	3.4	2.8	3.5	4.6	4.7	4.9	3.9	4.1	4.0
Tomisaki	5.0	5.0	5.0	4.6	4.5	4.7	4.6	4.4	4.8	5.2	6.0	5.5	5.0
Onahama	5.2	5.2	5.3	5.3	5.5	6.0	5.5	5.1	6.5	5.4	5.4	5.3	5.5
Miyako (Takonohama)	5.2	5.3	5.3	5.7	5.8	5.6	5.5	5.0	5.0	5.1	5.0	4.8	5.3
Hakodate	5.2	5.2	5.2	5.7	5.6	5.3	5.1	4.4	4.6	5.1	5.5	5.5	5.2
Urakawa	5.8	5.7	6.0	6.7	6.4	5.3	6.2	5.1	5.4	5.6	5.6	5.7	5.9
Oumu	6.3	6.8	7.1	7.1	7.0	6.4	5.9	5.9	6.0	6.0	6.5	6.4	6.1
Esashi	4.6	5.0	5.1	6.3	5.9	4.9	4.8	4.0	4.5	4.9	4.6	5.2	5.0
Aikawa	5.5	5.4	5.4	5.7	5.6	5.0	4.6	4.2	4.9	5.5	5.5	5.5	5.2
Wajima	5.6	5.4	5.8	5.7	5.4	4.6	5.2	4.3	5.0	5.4	5.6	5.7	5.3
Saigo	5.7	5.7	5.8	5.7	5.2	5.5	5.7	4.9	6.5	6.0	5.2	5.4	5.6
Shimonoseki	5.8	6.0	6.1	6.0	5.6	5.6	6.5	5.6	5.6	5.7	6.1	5.8	5.9
Izuhara	4.6	4.6	4.6	4.7	5.0	5.7	6.6	6.2	5.2	4.8	4.8	4.7	5.1
Tomie	4.7	4.8	4.8	4.9	4.3	4.7	4.6	4.4	4.8	5.2	4.9	4.7	4.7
Nagasaki	5.1	5.1	5.0	4.9	5.4	6.2	8.0	6.1	5.6	5.2	5.3	6.3	5.6
Hakodate-Aomori	5.1	5.0	5.0	5.0	5.1	5.3	5.1	4.6	4.5	4.7	5.0	5.0	5.0
Nagasaki-Goto	4.2	4.2	4.0	4.1	4.1	4.9	5.1	5.1	4.8	4.7	4.3	4.4	4.5
Saigo-Sakai	4.6	4.7	3.9	4.5	4.2	4.3	5.6	5.5	5.4	5.5	5.6	?	4.9
Ashizuri-misaki	4.4	4.4	4.5	4.3	4.3	5.2	6.0	6.1	5.4	5.2	3.6	4.8	4.9
Muroto-misaki	4.3	4.1	5.1	4.3	3.8	3.8	5.1	5.6	5.6	5.7	5.1	5.5	4.8
Hamajima	4.8	4.7	4.8	5.5	5.6	6.1	6.6	5.3	—	5.8	5.8	5.3	5.5

years before 1954. To these are added monthly averages derived from the results of weekly observations in 1954 at Ashizuri-misaki, at Muroto-misaki and in Kure, Hiroshima as well as those derived from every ten day observations in 1954 on board the ferry boat at the points lying midway between Hakodate and Aomori, between Nagasaki and Goto and between Saigo and Sakai respectively. Data at Hamajima are based on the observations carried out by the Fishery Experimental Station of Mie Prefecture and on the published data on monthly averages of ten years from 1931 to 1938 and from 1947 to 1950 by KOBAYASHI and WATABE (1953). At all those stations except the points between Nagasaki and Goto, chlorinities were calculated from specific gravities which were measured with a hydrometer. The annual change of temperature and chlorinity which takes place at each of the stations enumerated just above is shown in Figs. 20–43. Theoretical variation in the total cell number deducible from the monthly change of temperature and chlorinity at each of the stations is listed in Table II.

Various forms of annual cycles of temperature and chlorinity are devisible into several types. Diatom abundance in each type is described.

I. North temperate types: Belonging to this type are such stations as Oumu, Urakawa, Hakodate, Aikawa and Onahama (Figs. 20–23). At these localities diatoms flourish vigorously in spring and autumn. At Oumu, Urakawa and Esashi, however, they flourish much less in autumn than in spring, showing the characteristic of the boreal type rather than the temperate one. Onahama and Aikawa, on the contrary, show another small peak of diatom quantity in summer in addition to the peaks in spring and autumn, thus exhibiting the characteristic of the south temperate type to a certain extent.

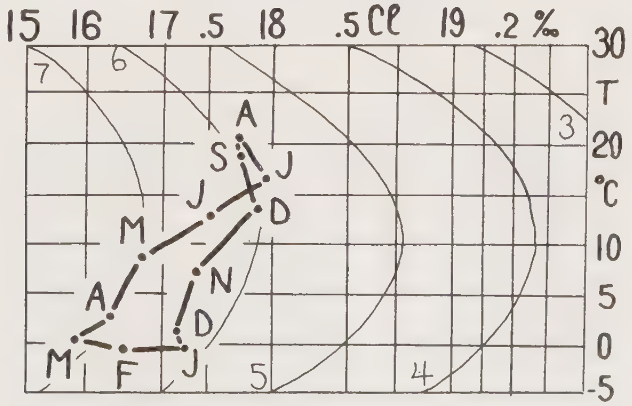

Fig. 20. Annual cycle of temperature and chlorinity at Oumu. Abbreviations as in Fig. 15.

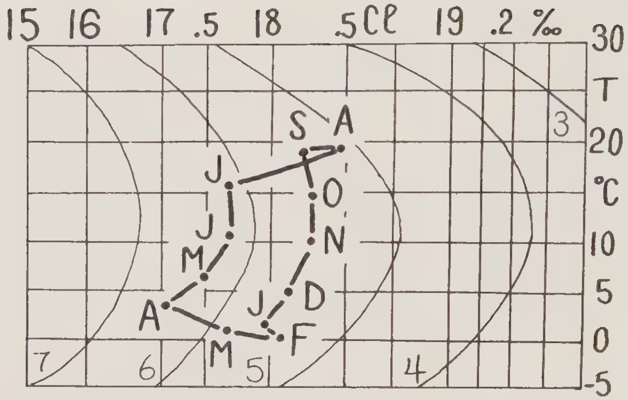

Fig. 21. Annual cycle of temperature and chlorinity at Urakawa. Abbreviations as in Fig. 15.

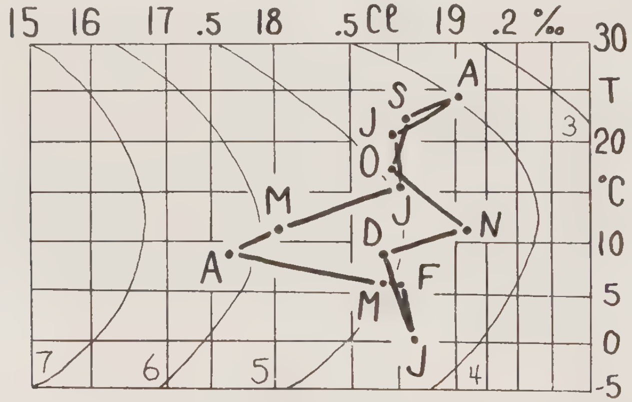

Fig. 22. Annual cycle of temperature and chlorinity at Esashi. Abbreviations as in Fig. 15.

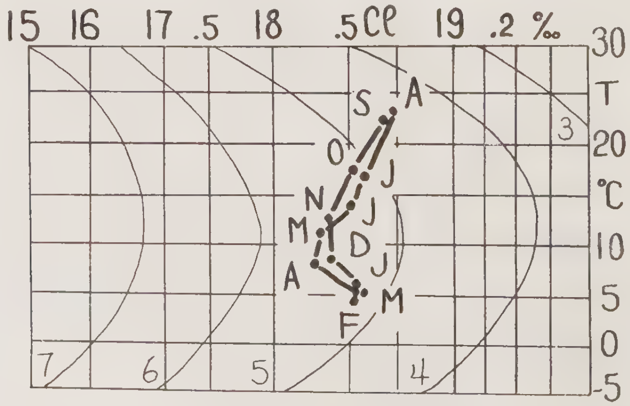

Fig. 23. Annual cycle of temperature and chlorinity in Hakodate. Abbreviations as in Fig. 15.

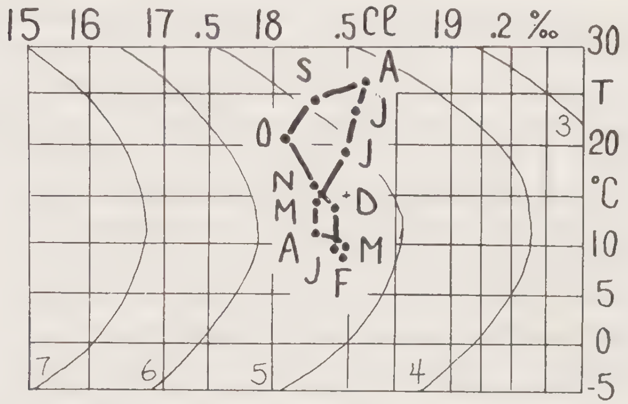

Fig. 24. Annual cycle of temperature and chlorinity at Aikawa. Abbreviations as in Fig. 15.

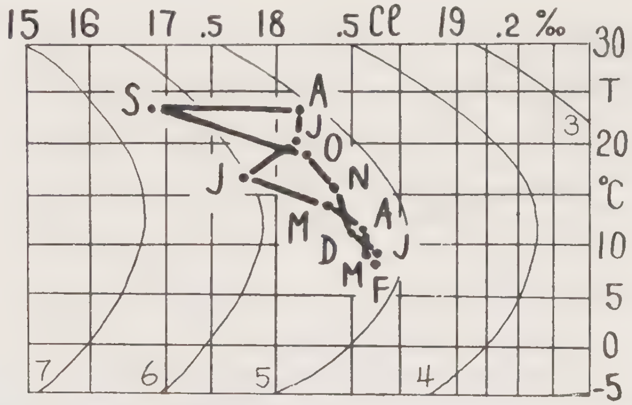

Fig. 25. Annual cycle of temperature and chlorinity at Onahama. Abbreviations as in Fig. 15.

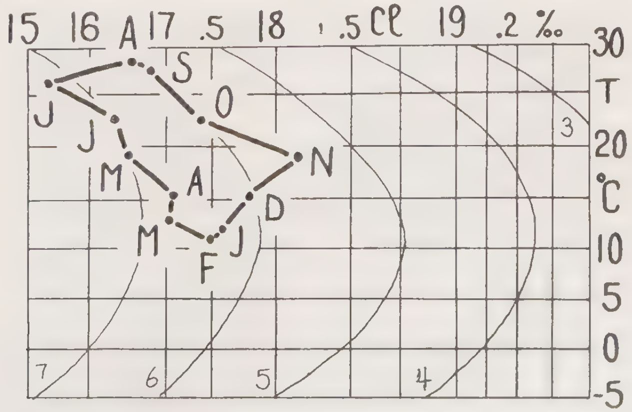

Fig. 26. Annual cycle of temperature and chlorinity at Uwajima. Abbreviations as in Fig. 15.

II. South temperate type: Uwajima, Kure, Hamajima, Owase, Saigo, Izuhara, Nagasaki, Tomie, Omaezaki, Wajima, Shimonoseki, Ashizuri-misaki and Muroto-misaki (Figs. 26–38) belong to this type. In these districts, as in Osaka Bay (Fig. 15), the diatoms flourish more abundantly in summer than in spring and autumn. At Ashizuri-misaki and Muroto-misaki, temperature in summer does not differ very much from that in winter. Productivity at these localities is relatively small on account of the fact that the cycle of temperature and chlorinity occupies its position in the relatively warm, haline part of the graph. At both of the localities, therefore, the characteristic of tropical type is more or less predominant. At Tomie the sea is also somewhat less productive. This may arise from the fact that the locality, having scanty land drainage, is under the great influence of Tsushima Current.

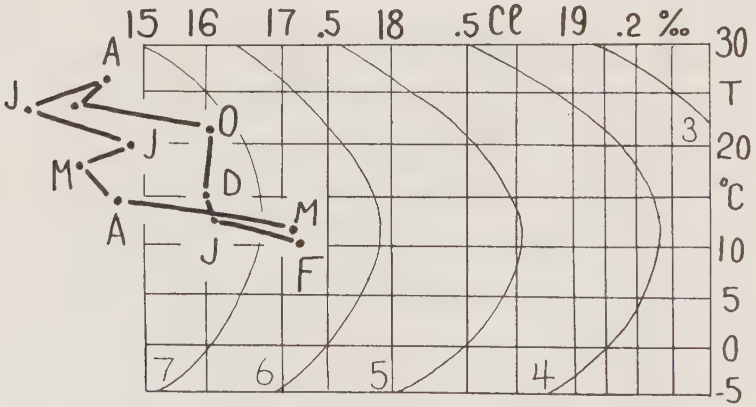

Fig. 27. Annual cycle of temperature and chlorinity at Kure. Abbreviation as in Fig. 15.

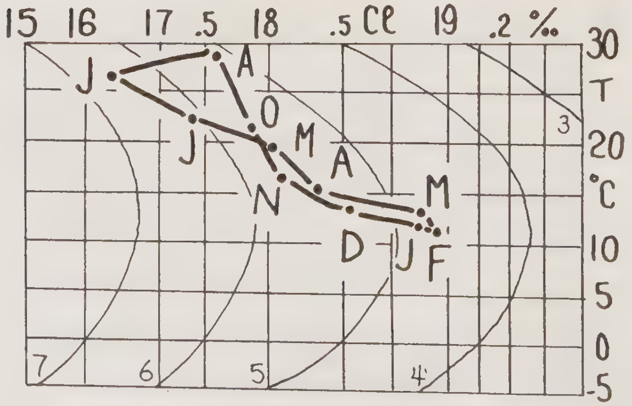

Fig. 28. Annual cycle of temperature and chlorinity at Hamajima. Abbreviations as in Fig. 15.

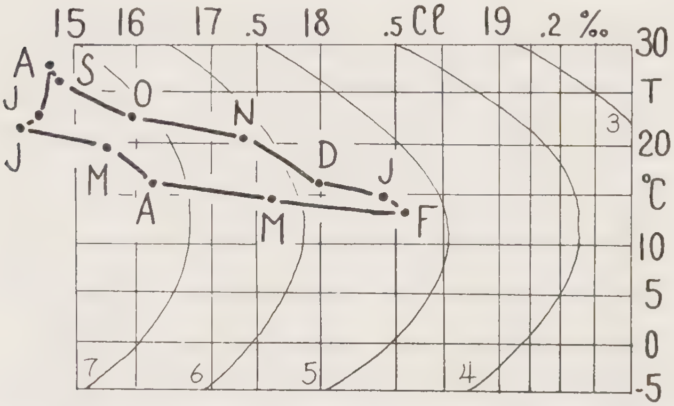

Fig. 29. Annual cycle of temperature and chlorinity at Owase. Abbreviations as in Fig. 15.

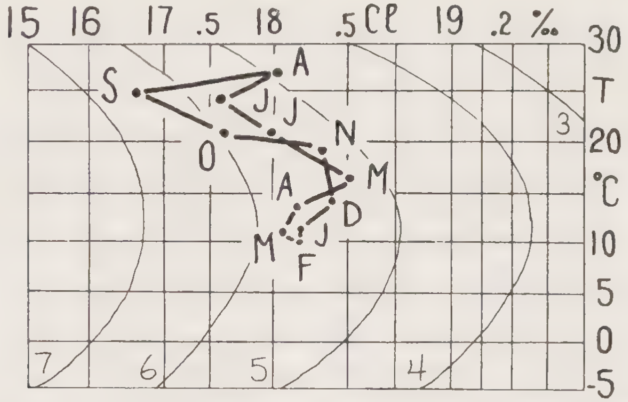

Fig. 30. Annual cycle of temperature and chlorinity at Saigo. Abbreviations as in Fig. 15.

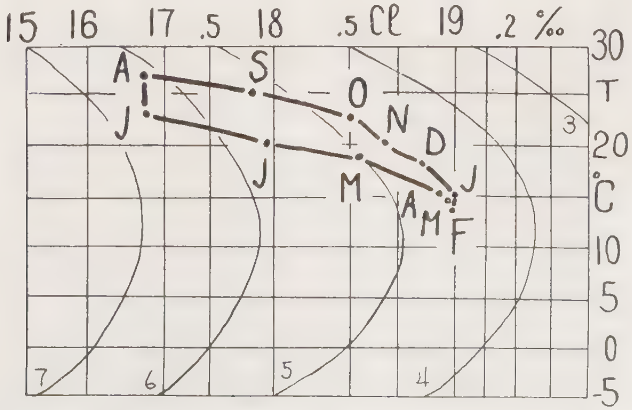

Fig. 31. Annual cycle of temperature and chlorinity at Izuhara. Abbreviations as in Fig. 15.

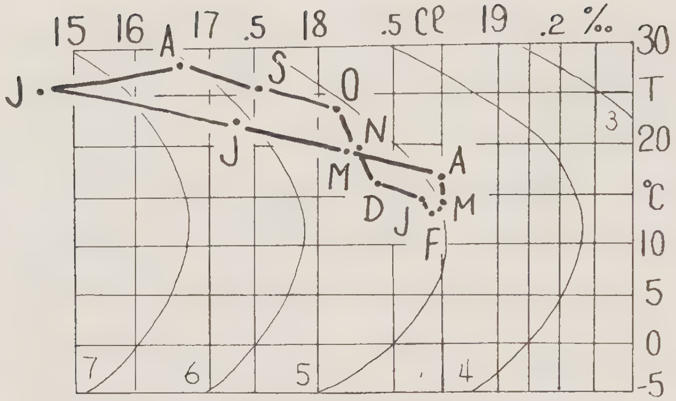

Fig. 32. Annual cycle of temperature and chlorinity at Nagasaki. Abbreviations as in Fig. 15.

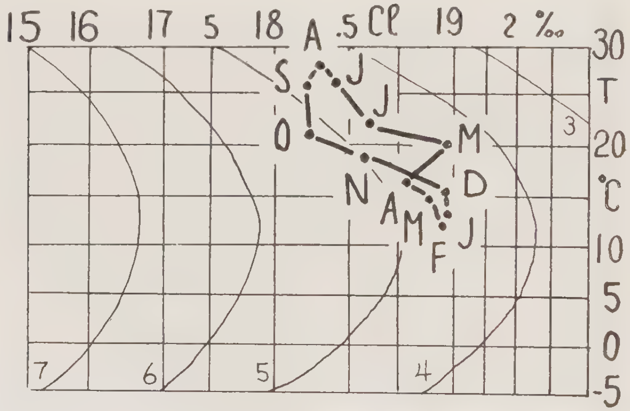

Fig. 33. Annual cycle of temperature and chlorinity at Tomie. Abbreviations as in Fig. 15.

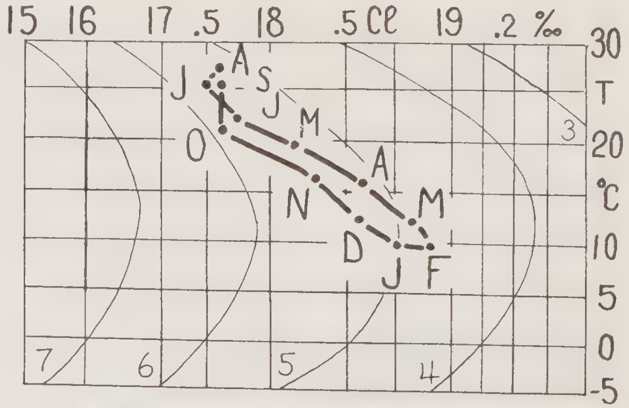

Fig. 34. Annual cycle of temperature and chlorinity at Omaezaki. Abbreviations as in Fig. 15.

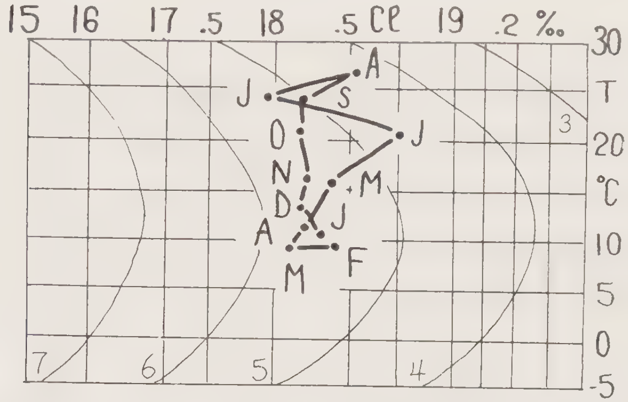

Fig. 35. Annual cycle of temperature and chlorinity at Wajima. Abbreviations as in Fig. 15.

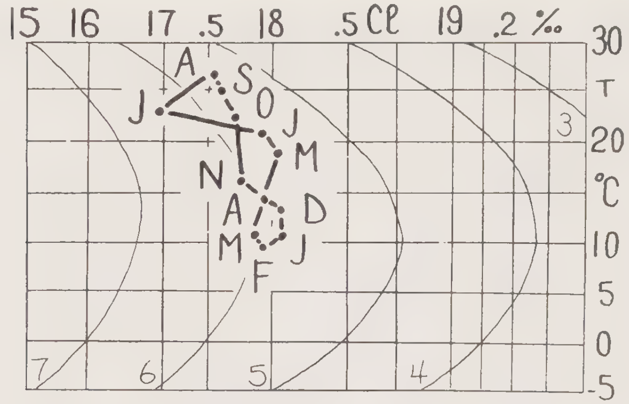

Fig. 36. Annual cycle of temperature and chlorinity at Shimonoseki. Abbreviations as in Fig. 15.

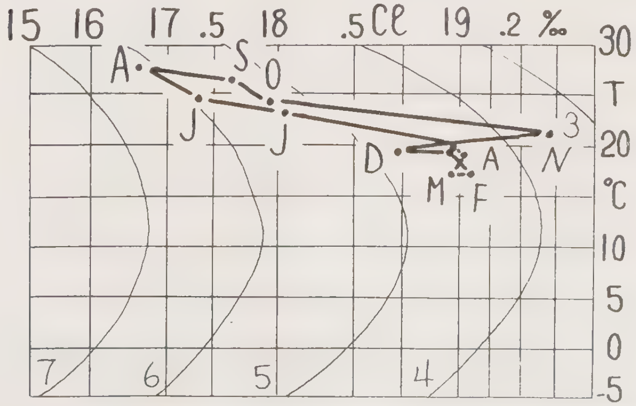

Fig. 37. Annual cycle of temperature and chlorinity at Ashizuri-misaki. Abbreviations as in Fig. 15.

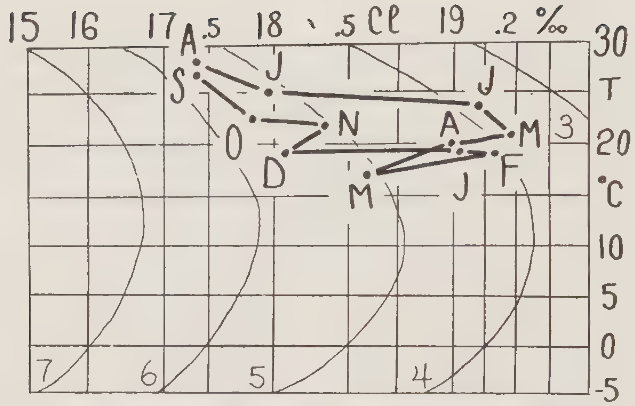

Fig. 38. Annual cycle of temperature and chlorinity at Muroto-misaki. Abbreviations as in Fig. 15.

III. Tropical type: Hachijyo-jima and Nase (Figs. 39 and 40) show the characteristics of this type. Annual fluctuation of temperature is slight and chlorinity is high throughout the year. The productivity is smallest of all the stations dealt with here.

IV. Exceptions: Miyako and Tomisaki (Figs. 41 and 42) are under the influence of oceanic waters from autumn to winter, while under that of neritic waters from spring to summer. At Tadotsu (Fig. 43) the situation is entirely reversed. Here, the chlorinity is high in spring and summer, but low from autumn to winter. This is the special feature of the eastern part of the Inland Sea.

Types of temperature-chlorinity cycles and annual mean of presumptive diatom cell numbers on the coast of Japan are summarized in Fig. 44.

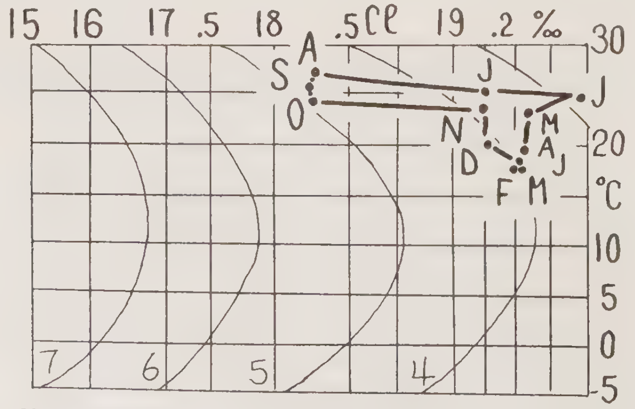

Fig. 39. Annual cycle of temperature and chlorinity in Hachijyo-jima. Abbreviations as in Fig. 15.

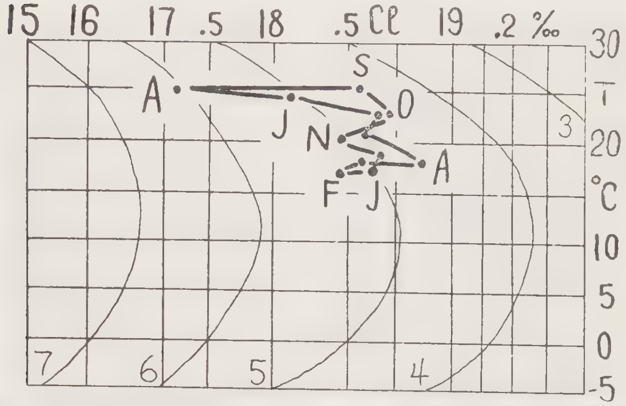

Fig. 40. Annual cycle of temperature and chlorinity at Nase. Abbreviations as in Fig. 15.

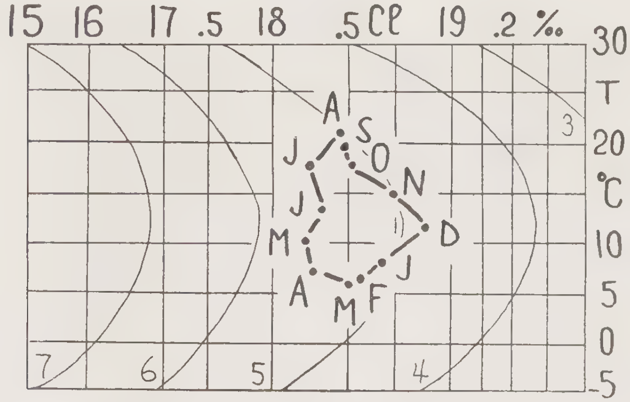

Fig. 41. Annual cycle of temperature and chlorinity at Miyako. Abbreviations as in Fig. 15.

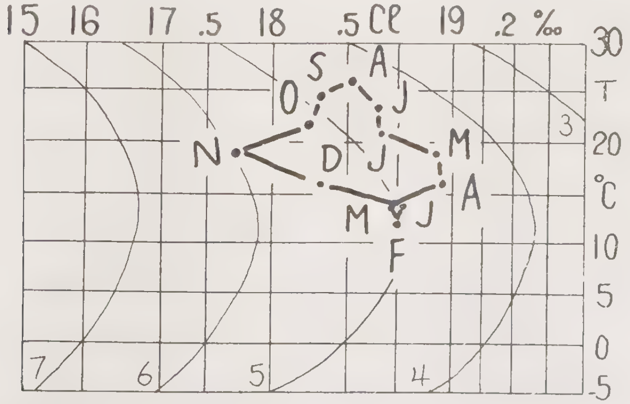

Fig. 42. Annual cycle of temperature and chlorinity at Tomisaki. Abbreviations as in Fig. 15.

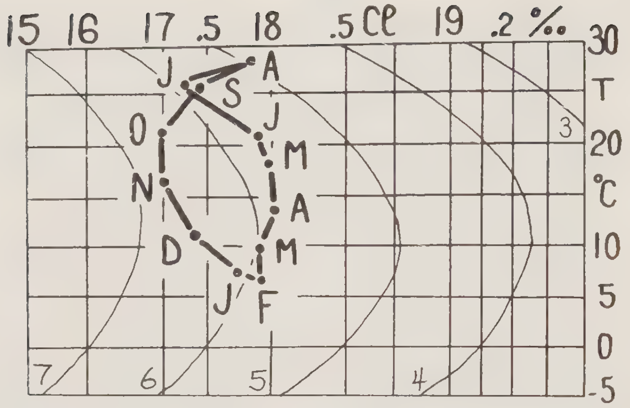

Fig. 43. Annual cycle of temperature and chlorinity at Tadotsu. Abbreviations as in Fig. 15.

Recently, the culture of pearl oyster in Ago Bay, Mie Prefecture has come to a standhill due to the over-crowding of the culture beds, and culturists are at present in search of new farms in the Inland Sea, or in the neighbouring seas of Kyushu and Shikoku. The most important factor in the environment of pearl oysters is the range of temperature, and perhaps also the chlorinity, which the pearl oyster (*Pteria* (*Pinctada*) *martensii* (Dunker)) prefers. Another important factor is the primary productivity, which is the basis of the nutrition of pearl oysters. In warm water with a above 28°C the mortality of the pearl oyster increases. With a temperature lower than 8°C in winter, not only is the vitality of the oyster greatly decreased, but also its growth during the following spring and summer is arrested to a certain extent (Kobayashi and Watabe 1959). As to the effects of chlorinity upon the pearl oyster nothing is known, except the immersion experiment in which the oyster has been immersed in the water with an exceedingly low chlorinity for several hours. Culture of the oysters over a long period of time in waters with various chlorinities ranging from 15 to 19 Cl ‰ hardly show any appreciable difference in their growth rate. In the range between 15 and 19.4 Cl ‰, the range which comes into question in the present paper, chlorinity does not appear to have any direct effect upon the oyster. In view of this, whether or not conditions are suitable for a culture farm ought to be determined primarily on the basis of the temperature range (8°–28°C), and high basic productivity. The basic productivity can be estimated by the temperature-chlorinity combination even if there is no observed data on the productivity. This is the main portion of the present study.

The annual cycle of temperature and chlorinity at Hamajima in Ago Bay, is shown in Fig. 28. Based on the comparison of the cycle at Hamajima and the one at other stations, the productivity in various localities are deduced indirectly.

At Hachijyo-jima as well as at Nase, although the temperature range is suitable, mass cultivation of pearl oysters at those localities may be unpracticable, since

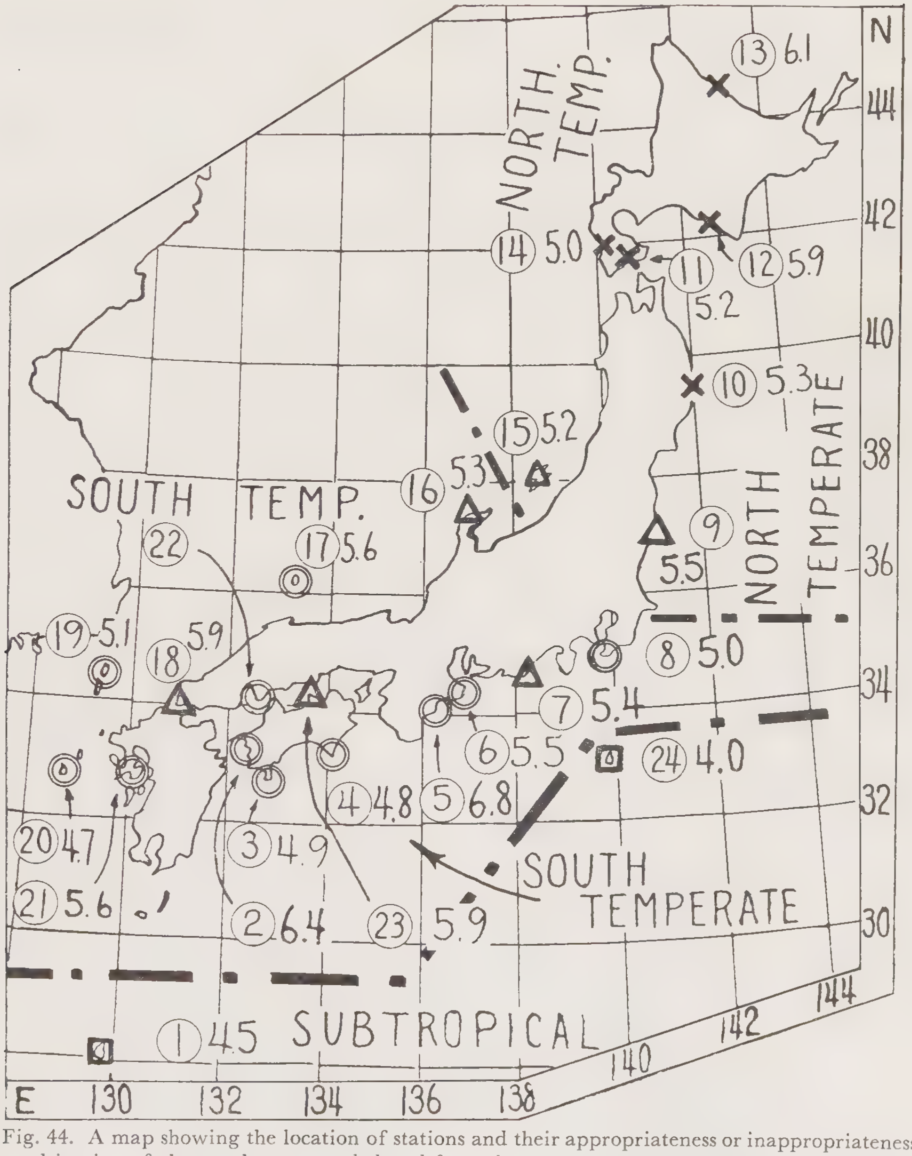

Fig. 44. A map showing the location of stations and their appropriateness or inappropriateness for cultivation of the pearl oyster as deduced from the temperature range as well as from basic productivity. The temperature records are based on actually observed data and the productivities are computed from temperature-chlorinity cycles (Figs. 20–43). The lines bordering the stations with different types of the annual cycles of temperature and chlorinity are indicated by thick chains. Numerals enclosed with single circles represent the stations: 1, Nase, 2, Uwajima, 3, Ashizuri-misaki 4, Muroto-misaki, 5, Owase, 6, Hamajima, 7, Omaezaki, 8, Tomisaki, 9, Onahama, 10, Miyako, 11, Hakodate, 12, Urakawa, 13, Oumu, 14, Esashi, 15, Aikawa, 16, Wajima, 17, Saigo, 18, Shimonoseki, 19, Izuhara, 20, Tomie, 21, Nagasaki, 22, Kure, 23, Tadotsu, 24, Hachijyo-jima. Numerals attched to the outside of each of them represent the annual mean of total cell numbers of diatoms (log cell1s/10 L). Double circle: the location of the station appropriate for the cultivation. Square: that of the station appropriate, but with a low productivity. Triangle: that of the station which is competent for the cultivation, but has a winter temperature dangerous for this. Cross: that of the station inappropriate for the cultivation.

the high chlorinity means low productivity. At Ashizuri-misaki and Muroto-misaki the chlorinity is also relatively high, but not as much as in the above-named stations, which are relatively less productive.

The annual cycles of temperature and chlorinity at Uwajima, Owase, Saigo, Izuhara and Nagasaki are almost identical with the one at Hamajima. The productivity at Uwajima may be a little larger than that at Hamajima, because the range of chlorinity at both stations are a little lower. At Saigo the productivity may be relatively good and, as at Uwajima, it is constant all the year round. At Izuhara, Nagasaki, Owase and Hamajima the productivity may be rather poor in winter. These stations are considered most favorable for cultivation. Although the seas of Tomisaki and Tomie are somewhat more haline and less productive than that of Hamajima, they are still perhaps suitable for cultivation.

The condition of the sea at Omaezaki is almost the same as that around Hamajima, although the mean temperature falls down to 9°C in winter. Since the temperature is represented by monthly average, the minimum temperature may fall to a lower degree. Recently, a number of new cultivation farms have been established in the neighbouring sea of Kure. Although the range of water temperature in Kure appears to be suitable for the cultivation, the productivity in this locality can not be estimated because of the exceedingly low chlorinity which is out of the scales of the graph (Fig. 27).

Tadotsu, located in the Inland Sea, has a wide range of temperature exceeding favorable limit for pearl oyster cultivation. The environmental conditions of Onahama, Aikawa and Wajima are similar to that of Tadotsu. The temperature occasionally drops in winter which would be dangerous for the pearl oyster. Shimomura (1953d) reported that in Nanao Bay at a point near Wajima pearl oyster culture was undertaken formerly, but this is not being continued at present. So far as his record shows the locality seems to be capable of pearl cultivation. Here, as at Omaezaki, the removal of culturing raft in winter would be necessary. The northern most limit of the distribution of wild pearl oyster extends to Tomisaki in the Pacific and Sado in the Japan Sea (Kobayashi and Watabe 1959).

Fig. 44 is a map showing the suitableness or unsuitableness of the stations will due consideration given to the above-mentioned facts. The seas adapted for cultivation are almost coincident with the area of south temperate type in the cycle of temperature and chlorinity.

V. Temperature-chlorinity preference in twenty-five dominant species occurring in the neighbouring seas of Japan

On the basis of the data gained by two series of surveys, the same as those dealt with in Chapter II, temperature and chlorinity preference of diatoms has been examined with respect to 25 leading species. Arrangement of the data has been

made in the following way. In each of the squares encompassed by the cross of the scales of temperature and those of chlorinity such as that shown in Figs. 8 and 9, the average of the numerals corresponding to that square has been taken. The averages represented in the diagram, however, are confined to those from the squares in which the frequency of appearance of the species goes beyond 50 %. The "frequency of appearance" is meant the number of slides, each of which has been taken from a single vial, in which the species in question can be found. It is represented by the percentage of such slides against those from whole series of vials corresponding to that square. Details on the results of calculation in each species and the errors caused by the counting of cell number together with the method of calculation have already been alluded to in some of the author's previous papers (Uyeno 1958d and 1959). In constructing the diatom quantity curves, the present paper chiefly used the data of Kobe Marine Observatory (1955–1958), and those of Kokubo (1931–1940) as supplement. Records of distribution without numerical treatment which were hitherto reported were also referred to in each species.

(1) *Asterionella japonica.* (Fig. 45)

Data were taken from Plankton Journal (Kokubo 1931–1940). Isometric curves showing rise and fall of the quantity of species are all convex toward the right side of the graph and their apices lie corresponding to about 15°C, indicating that the species is most prosperous at about this temperature. When the temperature remains at about this degree, the species attains to such an abundance as log 4 cells/10 L. at about 18.5 Cl ‰, but is reduced to log 3.5 cells/10 L. at about 19.0Cl ‰. Ranges of temperature and chlorinity in which this species occurs at the rate of more than log 3 cells/10 L are –5°–30°C and 17.0–19.3Cl ‰.

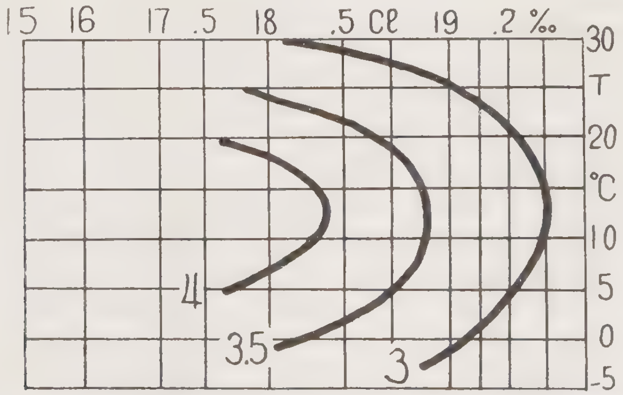

Fig. 45. Isometric curves of *Asterionella japonica* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

Allen (1928) reported that this species which is common at La Jolla propa-

gates most favorably at temperatures of 12.°5–15.°0C and at Point Hueneme it is found in the largest numbers at 12.°0–14.°0C. Sleggs (1927) recorded the large catches of the species at temperatures of 17.°77–19.°51C on the same coast and the largest one at 19.°51C. At Dröback in Olso Fjord, a large number of *A. japonica* is said to be found at temperatures less than 5.°4–8.°0C and at salinities of 33.60–35.00 ‰ (18.60–19.37 Cl ‰) (Gran 1929). In Aomori Bay the species is recorded from the area ranging from 5.°2 to 24.°5C in temperature and the largest catch is obtained within the range of 19.°6–17.°0C (Kokubo, 1932). At Scotch Cap, Alaska the individuals are abundant on the surface with the temperatures of –0.°67–9.°67C and with the salinities of 30.58–31.91 ‰ (16.92–17.66 Cl ‰) the majority of large catches are got at 6.°64–9.°63C and in 30.58–31.82 ‰ (16.93–17.61 Cl ‰) (Cupp 1937). 9.°6C is the maximum of the whole year at Scotch Cap and this may also represents the condition at Dröback. The ranges of temperature and chlorinity in those districts are narrower than the actual ranges which were mentioned in the present paper. So far as the species can not be considered to have different ranges according to various districts, the ranges given by the authors enumerated above may represent each no more than a small part of the actual ranges.

Marumo (1954) recorded the occurrence of the species in Truck Lagoon. There was no record of this species from the Antarctic Ocean (Boden 1949; Tsubata 1950; Marumo 1953a, b, 1957). Although Cupp (1943) said the species is neritic, south temperate and wide-spread species, it is doubtful whether it really belongs to south temperate species. It is thought that the species distributes widely ranging from boreal to tropical waters.

(2) *Bacteriastrum varians.* (Fig. 46)

Data were taken from Kobe Marine Observatory (1955–1958). In the ranges of temperature from 10° to 30°C and of chlorinity from16 to 19.3 Cl ‰ this species makes its appearance at the average rate more than log 3 cells/10 L. The maximum occurrence is met with at 20°C and 16–17.5 Cl ‰. Shimomura (1953 a, c) recorded that the optimum range of temperature falls between 15° and 20°C and that of chlorinity is lower than 18 Cl ‰. He farther said that this species was not found from Tokyo Bay to Hachijyo-jima at a temperature lower than 15°C. He regarded it as euryhaline, warm water form. Hustedt (1930) as well as Kokubo (1955) were of the opinion that it is a neritic, cosmopolitan form. Cupp (1943) also regarded it as neritic.

B. varians does not occur in colder waters, such as the Bering Sea (Marumo 1956, Kawarada 1957 and Karohji 1958), the Aleutian waters (Cupp 1937, Motoda and Kawarada 1955, Tsuruta and Chiba 1954, Kawarada and Ohwada 1957 and Takano 1959) and the Okhotsk Sea (Ohwada 1957). It is also unrecorded from tropical waters, such as the Palao Lagoon (Tokioka 1942), the Truck Lagoon (Marumo 1954) and the sea around Marshall Islands (Kitou 1953).

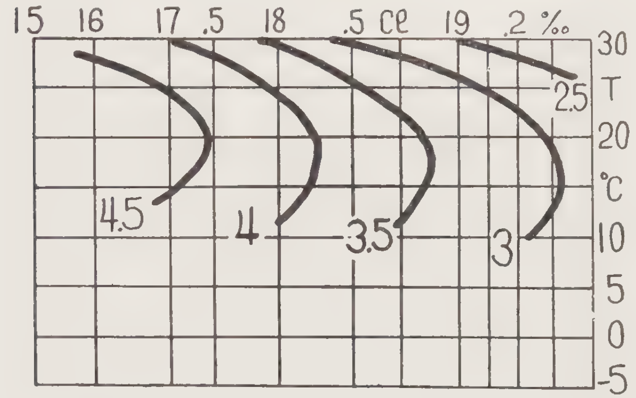

Fig. 46. Isometric curves of *Bacteriastrum variaus* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number individuals are represented by log cell number/10L. Abbreviations as in Fig. 13.

Considering the curves and those records, it is rather doubtful that the species is cosmopolitan. The author is of the opinion that *B. varians* belongs to a neritic, south temperate species.

(3) *Biddulphia aurita*. (Fig. 47)

Data were taken from Plankton Jornal (Kokubo 1931–1940). In the seas from which the collection was made by Kobe Marine Observatory (1955–1958) no individual is found. Of all the species dealt with in the present section, *B. aurita* is best adapted for cold water life. Mainly appearing at a temperature below 10°C, it is most abundant near 0°C and 16.0–16.5 Cl‰. It deserves the name of neritic, cold

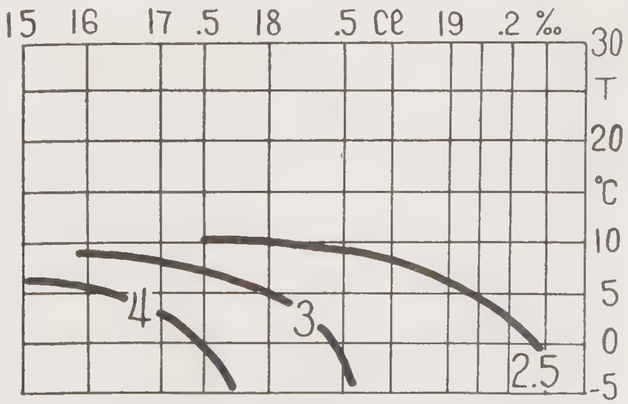

Fig. 47. Isometric curves of *Biddulphia aurita* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

water species. According to Gaarder and Gran (1927), the species occurs in Dröback Fjord most abundantly in March, when the water is 1.°7C in temperature and 30.06‰ in salinity (16.64 Cl ‰ in chlorinity). At Scotch Cap, Cupp (1937) found the largest yields of the species at 1.°63–3.°96C in temperature and 30.60–31.95 ‰ in salinity (16.84–17.68 Cl‰ in chlorinity). On the coast of the Aleutian Islands it is found only in a small number (Motoda and Ohwada 1957) and it has never been recorded in the Bering Sea (Ohwada 1957). Cupp (1937) regarded it as neritic and arctic species.

(4) *Chaetoceros affinis.* (Fig. 48)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (1931–1940). *Chaetoceros affinis* is very wide in its distribution both in chlo-

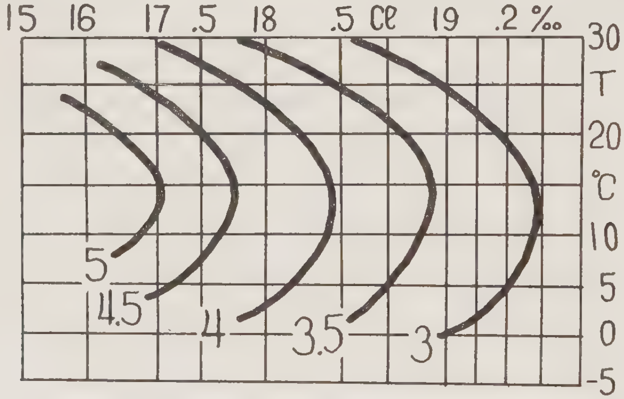

Fig. 48. Isometric curves of *Chaetoceros affinis* showing the changs in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

rinity and temperature. Below 10°C, temperature manifests its effect in the form of decrease in number. This is also distinct in much warmer water with high chlorinity. The species is reduced most frequently occurs at the temperature of 15°C and at the chlorinity less than 17 Cl ‰. Gradients of quantity are rather steep against chlorinity. The species is reduced in its quantity to less than 1000 cells/10 L in warm water with high chlorinity, i. e. at the temperature surpassing 25°C and at the chlorinity of 19 Cl ‰.

Shimomura (1953a) reported that the species occurs in neritic, temperate seas, being commonly founds around Japan. According to him, the species is found in the sea ranging from Tokyo Bay to Hachijyo-jima throughout the year and abundantly occurs at temperatures between 10° to 15°C and between 23° to 27°C. The present study, however reveals that the range of the most frequent occurrence lies between those two. Shimomura (1953b) stated in another paper, that in the region between

Tokyo and Hakodate, the species does not occur, when the water temperature is less than 10°C, but he found in another that it occurs at temperatures from 4.°2 to 29.°8C in Nanao Bay (SHIMOMURA 1953c). As to the relation between the frequency of this species and chlorinity, he did not recognize any close connection (SHIMOMURA 1953a). It appears, however, the optimum range of chlorinity lies below 19.0 Cl ‰. Outside the Japanese waters, the species is found in the tropical Pacific (TOKIOKA 1942, KITOU 1952). In colder waters, it occurs only at Scotch Cap (CUPP 1937), but does not occur in the Bering Sea (MARUMO 1956, KAWARADA 1957 and KAROHJI 1958) and the Aleutian waters (TSURUTA and CHIBA 1954, MOTODA and KAWARADA 1955, KAWARADA and OHWADA 1957). CUPP (1943) considered the species as neritic and south temperate inhabitant. She appeared to be right, since in cold waters, in which the temperature does not reach 10°C in the maximum, e.g. at Scotch Cap (CUPP, 1937) and in Friday Harbor (JOHNSON 1932), the abundant occurrence of the species has never been recorded. KOKUBO (1955) described *C. affinis* as being eurythermal and distributing widely from tropical to colder waters. It is doubtful, however, the species may occur abundantly in cold waters.

(5) *Chaetoceros affinis* v. *willei*. (Fig. 49)

In the presents study, *Chaetoceros affinis* v. *willei* was found in such a small quantity that an accurate calculation of averages is impossible. The range of its occurrence shown in Fig. 49 corresponds to the peripherical range of the isometric curves of *C. affinis* (Fig. 48). This tells us that the variety represents another form of *C. affinis* which is adapted for unfavorable environments. KOKUBO (1955) took it for the winter type of *C. affinis* and OSTENFELD (1913) considered it as winter and oceanic type. In the opinion of the present author, the view of the latter is preferable. It appears that KOKUBO (1955) was short of oceanic samples. In the sea around Honshu, Japan, the variety *willei* is ordinarily found offshore (UYENO 1958d) and it

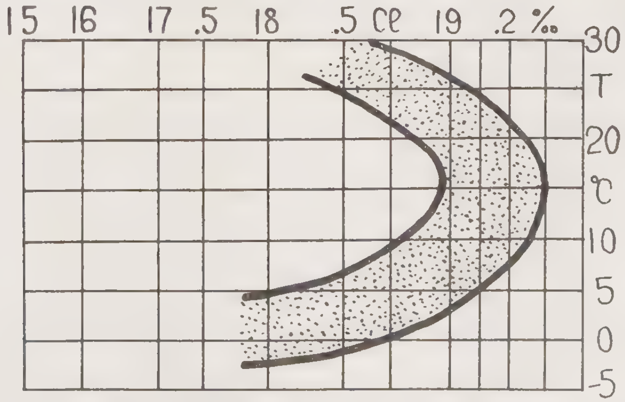

Fig. 49. Range of *Chaetoceros affinis* v. *willei* represented by dotted band according to the various combinations of temperature and chlorinity. Abbreviations as in Fig. 13.

makes its appearance inshore waters of Hokkaido in winter season only (Akatsuka 1914 and Kokubo 1955). Takano (1955) mentioned the species as appearing in summer in the neritic, or subneritic zone in the western Aleutian waters. Those records agree quite well with the state of things shown in Fig. 49.

(6) *Chaetoceros compressus.* (Fig. 50)

Data were taken from Kobe Marine Observatory and Plankton Journal (1931–1940). The curves of *Chaetoceros compressus* are almost the same as those of *C. affinis* in their features. The species is rather broad in the range of temperature and chlorinity of its occurrence. At about 15°C and at 15 Cl ‰ or less the species is most abundant and decreases more gradually than in *C. affinis* in warmer or colder waters. Shimomura (1953a, b) reported that in the seas ranging from Tokyo Bay to Hachijyo-jima the species appears at temperatures of 9°–26°C, but disappears at 17°–23°C. He stated that the chlorinity has no effect on the frequency of the ap-

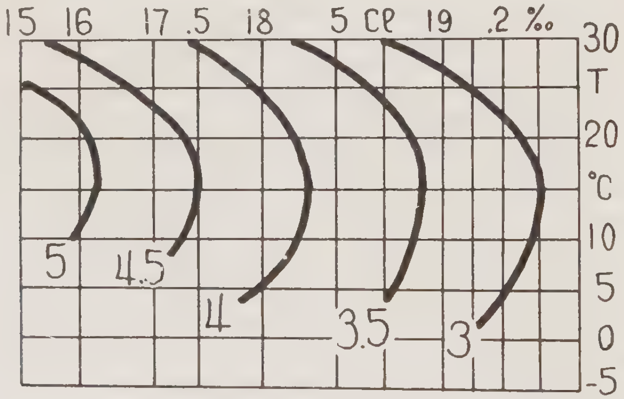

Fig. 50. Isometric curves of *Chaetoceros compressus* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by cell number/10 L. Abbreviations as in Fig. 13.

pearance. Both of the temperature ranges recorded by Shimomura (1953a) in which this species occurs come within the two extreme limits indicated in the graph (Fig. 50). Disappearance of the species at temperatures of 17°–23°C may have arisen from too large a dilution of the sample at the time of cell counting. Cupp (1943) called it a neritic species occurring from boreal to south temperate zones. Hustedt (1930) and Kokubo (1955) maintained that the species is "Neritic in all europian waters very widely distributed from tropics to polar waters." Records from cold waters in north-western Pacific are: the Bering Sea (Kawarada 1957 and Karohji 1958), the western Aleutian waters (Takano 1959) and the Okhotsk Sea (Ohwada 1957). The species is unrecorded from the Antarctic (Boden 1949, Tsubata 1950, Marumo 1953a, b, 1957).

(7) *Chaetoceros curvisetus.* (Fig. 51)

. Data were taken from Kobe Marine Observatory (1955–1958). The species shows the features of relatively widely distributed, neritic species. It is most abundantly found at about 20°C in temperature and at 15 Cl‰ or less in chlorinity. The quantity of the species is considerably reduced in the higher range of temperature and chlorinity. Increase and decrease in quantity according to the change of temperature and chlorinity are somewhat more sensitive than in *C. compressus.* According to Shimomura (1953a, b), the species is found at temperatures of 10°–15° and 20°–26°C. The former range lies near the range of most abundant occurrence in Fig. 51. The species is unrecorded from northern cold waters such as the Ok-

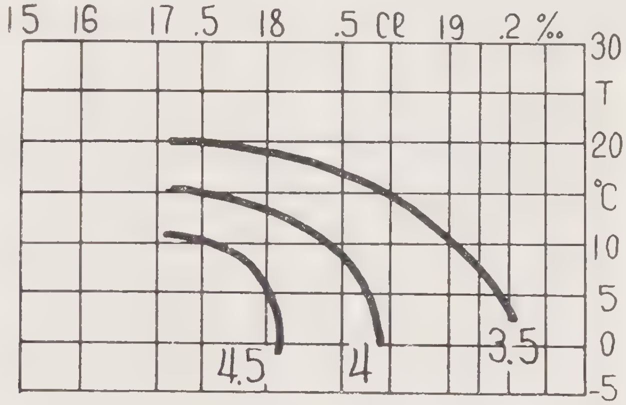

Fig. 51. Isometric curves of *Chaetoceros curvisetus* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

hotsk Sea (Ohwada 1957), the Aleutian waters (Takano 1959 etc.) and the Bering Sea (Karohji 1958 etc.). It occurs at Scotch Cap (Cupp 1943), and also in tropical waters, such as the lagoons in Truck (Marumo 1954), Palao (Tokioka 1942) and Marshall Islands (Kitou 1952). Cupp (1943) regarded it as neritic and south temperate in occurrence, but Shimomura (1953 a) regarded it as cosmopolitan. The author supports the former's view.

(8) *Chaetoceros debilis.* (Fig. 52)

Data were taken from Plankton Journal (Kokubo 1931–1940). *Chaetoceros debilis* is abundant in colder water with low chlorinity. It appears in greatest quantity at 5°–10°C and at 16–17.5 Cl‰. Although Hustedt (1930), Cupp (1934) and Kokubo (1955) regarded the species as neritic inhabitant, it is abundantly found in the chlorinity above 19 Cl‰. At Scotch Cap maximal population is found in the temperature range of 1.°87–7.°69C and in the salinity range of 30.28–31.82‰ (16.76–17.61 Cl‰ in chlorinity) (Cupp 1937). Gran and Thompson (1930) found the maximum

population in the San Juan Archipelago at 16.°8C and Cupp in lower California from 14.°4 to 18.°2C. Kokubo (1932) stated that the species is distributed at temperatures of 5.°2–25.°0C and in the greatest numbers at 5.°2–12.°0C. Shimomura (1953b) reported that in the sea ranging from Tokyo Bay to Hakodate the optimum range of temperature for occurrence of the species is 10°–15°C and that of chlorinity is 18.7–18.9 Cl ‰. From these records, it may be deducible that the range of temperature for the abundance of the species is 5°–20°C and which most prevalence at 10°–15°C. Cupp (1937) regarded *C. debilis* as neritic, north temperate form.

Hustedt (1930) claimed, it is "Vielleicht euryhaline". It seems that increase or decrease in the quantity of this species is rather gradual in proportion to the change of chlorinity. The range of chlorinity in which the species occurs is rather broad. The paths of the isometric curves tell that *C. debilis* does not necessarily serve as an indicator of water mass.

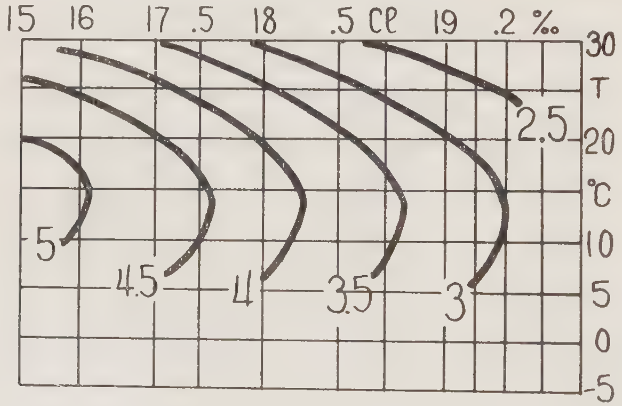

Fig. 52. Isometric curves of *Chaetoceros debilis* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(9) *Chaetoceros decipiens.* (Fig. 53)

Data were taken from Plankton Journal (Kokubo 1931–1940). In the data of Kobe Marine Observatory (1955–1958), the species was so scarce, that the calculation of averages was impossible. Similarly to *C. affinis*, *C. compressus* and *L. danicus*, this species appears within a very broad range of temperature and chlorinity. *Chaetoceros decipiens* is abundantly found in the sea with a temperature of 5°–20°C and in the range lower than that favorable to *C. affinis*, or to *C. compressus*, though it can endure a temperature beyond 30°C. In the sea extending from Tokyo to Hakodate, Shimomura (1953b) discovered the species at a temperature higher than 10°C. Smayda (1958) reported that the lowest salinity which the species can bear lies between 7 ‰ and 15 ‰ (4–8 Cl ‰). The species was regarded by Cupp (1943) as an oceanic,

arctic, boreal inhabitant and by KOKUBO (1955) to live mainly in colder waters, although covering a far broader area. The north temperate regions, such as the north-western Pacific (MOTODA and KAWARADA 1955, TSURUTA and CHIBA 1954, KITOU and ASAOKA 1956 and 1957 etc.) and the southern part of the North Sea (GRØNTVED and STEEMANN NIELSEN 1957), are richly inhabited by the species, while the colder water, such as in Scotch Cap (CUPP 1937) and the Bering Sea (MARUMO 1956), is less populated. When *C. debilis* occurs abundantly in the north temperate region, *decipiens* is much reduced in quantity (MOTODA and KAWARADA 1955, KAROHJI 1958 etc.). Although the isometric curves for the present species shown in Fig. 53 exactly represent the actual state of things in a lower temperature, they are somewhat unreliable in a higher temperature. It appears that the data on *C. lorenzianus* may have been intermingled with those of this species.

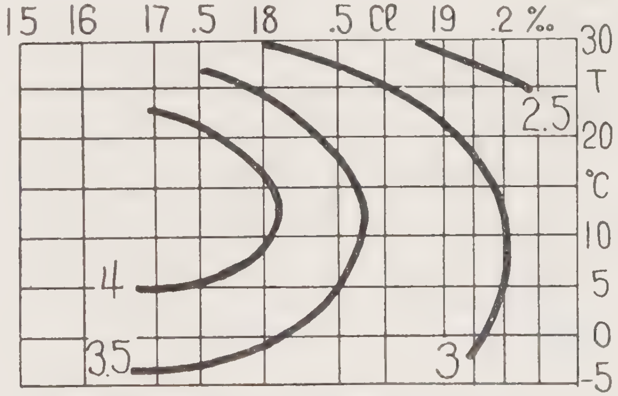

Fig. 53. Isometric curves of *Chaetoceros decipiens* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(10) *Chaetoceros didymus*. (Fig. 54)

Data were taken from Plankton Journal (KOKUBO 1931–1940). The species is abundant at a temperature of about 20°C and a chlorinity of 17.0 Cl ‰ or less. It may be able to endure relatively cold water of about 5°C, since KOKUBO (1955) stated that it is distributed from the southern water to the northern, although it lives chiefly in the former. According to SHIMOMURA (1953a), in the sea ranging from Tokyo Bay to Hachijyo-jima it occurs at a temperature between 10° and 25°C and at a chlorinity between 18 and 19.3 Cl ‰; the largest number is at a temperature of 15°–17°C and 23°–25°C and with a chlorinity of 19–19.3 Cl ‰ and 17–18 Cl ‰. Its occurrence is relatively rare in cold waters. There are only two records of it, one from Scotch Cap (CUPP 1937) and the other from the Antarctic Ocean (BODEN 1949). As pointed out by CUPP (1943), *C. didymus* is considered as a typical neritic, south temperate species. In the seas with a temperature higher than 20°C and with

a chlorinity higher than 19.0 Cl‰, e.g., in Kuroshio, the species is rather scarce.

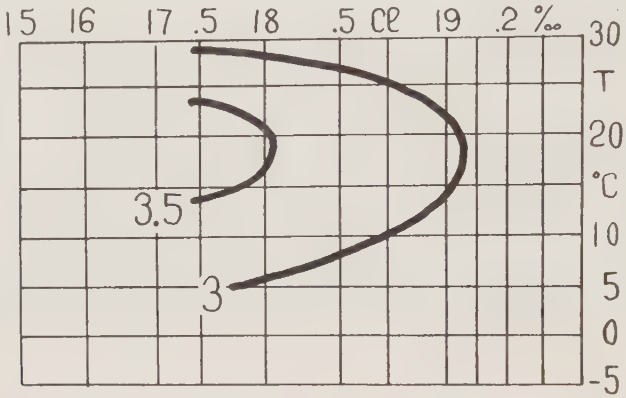

Fig. 54. Isometric curves of *Chaetoceros didymus* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(11) *Chaetoceros distans* (*C. laciniosus*). (Fig. 55)

Data were taken from Kobe Marine Observatory (1955–1958). Isometric curves are almost similar to those of *C. affinis*, or of *C. compressus*, though their gradients of quantity against chlorinity are slightly larger. The species is found most abundantly at a temperature of 10°–20°C and at a chlorinity of less than 17 Cl‰. As the frequency of appearance in the vials is rather low, the averages here presented are somewhat unreliable. Therefore, it is shown that the reduction in quantity is more conspicuous in higher chlorinity than in the lower. According to Smayda

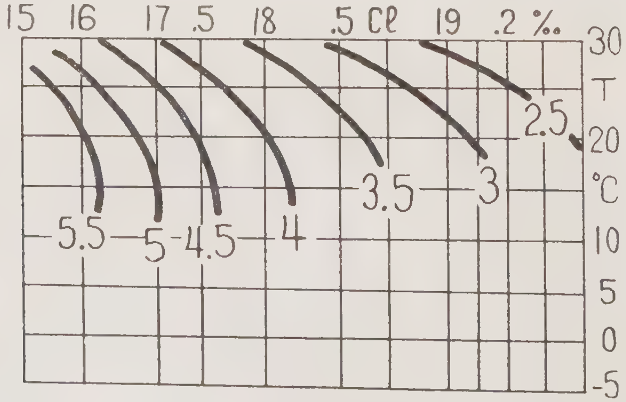

Fig. 55. Isometric curves of *Chaetoceros distans* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(1958), the lowest salinity which this species can bear lies between 7 and 15 ‰ (4 to 8 Cl ‰). In Nanao Bay the optimum range of temperature for the species lies between 15° and 20°C (SHIMOMURA 1953a). These facts tell us that *Chaetoceros distans* belongs to neritic, widespread, warm water species. Although HUSTEDT (1930) held the present species to be a synonym of *C. laciniosus*, KOKUBO (1955) and AKATSUKA (1914) took the two as distinct. Except for CUPP's record from Scotch Cap, *C. laciniosus* is not recorded in cold waters, e.g. the Bering Sea (KAROHJI 1958, etc.) or the Aleutian waters (TAKANO 1959, etc.).

(12) *Chaetoceros subsecudus*. (Fig. 56)

Data were taken from Plankton Journal (KOKUBO 1931–1940). Of all the species here dealt with, *Chaetoceros subsecundus* belongs to one of a few neritic, cold water species. It is most abundant at a temperature lower than 10°C and at a chlorinity lower than 17 Cl ‰. Isometric curves are unreliable at temperatures exceeding 10°C and at chlorinities over 18 Cl ‰. It is reliably true that the habitat of the species may extend to relatively warm waters. Although CUPP (1943) said that the species inhabits the north temperate seas, it seems to be more prevalent in warm waters than other cold water species, e.g. *C. debilis* or *Biddulphia aurita*. This agrees well with KOKUBO's statement (KOKUBO 1955) that it prevails both in warm and in cold waters.

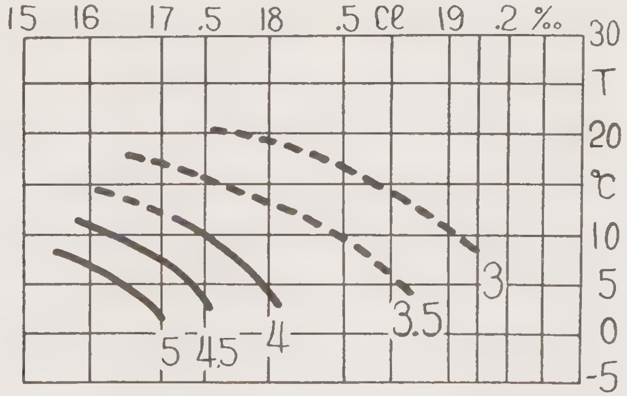

Fig. 56. Isometric curves of *Chaetoceros subsecundus* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig.13.

(13) *Dactyliosolen mediterraneus*. (Fig. 57)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (KOKUBO 1931–1940). *Dactyliosolen mediterraneus* is a neritic, widely distributed warm water species and most abundantly found at a temperature of about 15 C and

presumably in a chlorinity of 16–17 Cl ‰. In low chlorinities the species is very scarce in spite of the relatively high frequency of its appearance in vials. This is in accord with the statements of Cupp (1943) and Kokubo (1955), the former of whom states "the species is neritic, sporadically oceanic". The species is abundantly found even at very low temperature of about −1°C in the Antarctic Ocean (Marumo 1953).

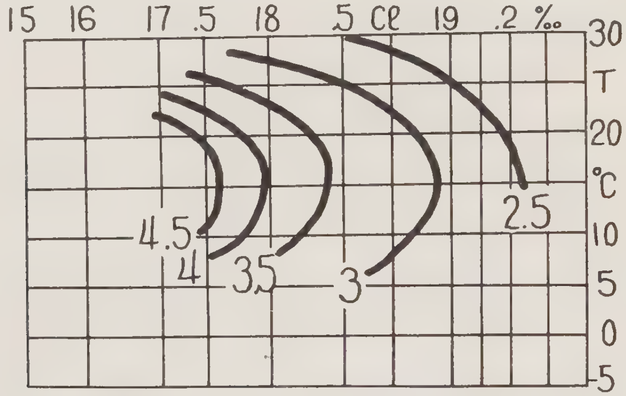

Fig. 57. Isometric curves of *Dactyliosolen mediterraneus* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(14) *Eucampia zoodiacus*. (Fig. 58)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (Kokubo 1931–1940). Curves of *Eucampia zoodiacus* tell that the species represents a cold water type, in spite of its capability of living in somewhat warmer waters. Waters with a temperature above 25°C are almost destitute of this species, while the waters with temperatures of 7.°5–15.°0C and with chlorinities of less than 16 Cl ‰ are most abundantly populated. Despite the fact that the gradients of the variation in quantity of the species is comparatively large against chlorinity, the distribution of the species extends well to a rather high chlorinity. Shimomura (1953b), in his survey made in the sea ranging from Hakodate to Tokyo, has found that the species occurs at temperatures of 10°–15°C and in chlorinities of 18.6–18.9 Cl ‰. It occurs somewhat rarely in cold waters. At Scotch Cap (Cupp 1930) it is not included among the predominant species. It was recorded by Motoda and Kawarada (1955) from the south eastern sea of the Aleutian, but unrecorded from the west of those islands (Tsuruta and Chiba 1954, Kawarada 1957 and Takano 1959) as well as from the Okhotsk Sea (Ohwada 1957) and from the Bering Sea (Marumo 1956 and Karohji 1958). Marumo (1953 b), who had recorded the species from the Antarctic Ocean, did not recognize its occurrence in his later report (Marumo 1957) in the same ocean on 1954–1955 cruise. From these records, it may

be concluded that the distribution of *zoodiacus* extends even to arctic waters, though the species is strongly reduced in number in those waters. All the isometric curves shown in Fig. 58 would turn to the left in lower temperature less than 10°C, if the materials needed for the drawing of the curves could be obtained. Although *zoodiacus* was considered by Cupp (1943) as south temperate species, it ought to be regarded preferably as belonging to a cold water species as pointed out by Hustedt (1930) and Kokubo (1955).

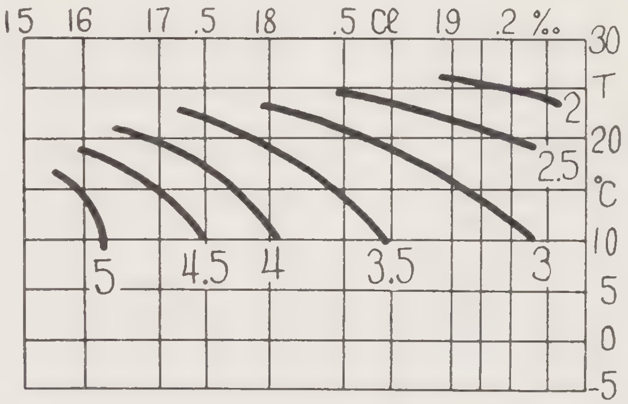

Fig. 58. Isometric curves of *Eucampia zoodiacus* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(15) *Hemiaulus hauckii*. (Fig. 59)

Data were taken from Kobe Marine Observatory (1955–1958). Distribution of *Hemiaulus hauckii* covers a very broad area, but due to the rarity of its occurrence, decrease or increase in quantity according to the change of chlorinity is represent to be very small in Fig. 59. It is most abundand at a temperature of 10°–15°C and in a chlorinity lower than 17.0 Cl ‰. The species has never been recorded from boreal waters further north to the North Pacific. Its distribution may exactly be expressed by Cupp's (1943) words that "Oceanic or neritic, temperate and tropical species. Not uncommon, but never in large numbers". Neverthless, it is unrecorded from the lagoons at Palao (Tokioka 1942) and Truck (Marumo 1954) and from the sea around the Marshall Islands (Kitou 1952).

(16) *Leptocylindrus danicus*. (Fig. 60)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (1931–1940). This species has a very wide distribution. Unless the chlorinity is high, decrease in quantity related to the rise of temperature in warmer seas, or with its fall in colder seas is not very large. The temperature at which the species

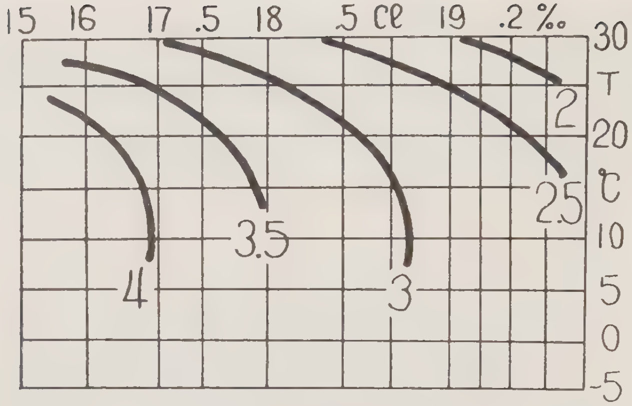

Fig. 59. Isometric curves of *Hemiaulus hauckii* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

is most abundant is over 20°C and that which it inhabits ranges ordinarily from 5° to 25°C. Gradients of quantity in relation to the change of chlorinity is rather large and the densest population is found in the waters lower than 16 Cl ‰. Smayda (1958) reported that the minimum salinity under which the species is viable lies between 7 and 15 ‰ (4–8 Cl ‰). The occurrence of the species was recorded from the Truck Lagoon by Marumo (1954), but unrecorded from the Marshall Islands by Kitou (1952). In cold waters, on the other hand, the species is found at Scotch Cap by Cupp (1937), in the Okhotsk Sea by Ohwada (1957), in the western North Pacific and in the Aleutian waters by Kawarada and Ohwada (1957) and Takano (1959). It was not discovered by Motoda and Kawarada (1955) and by Tsuruta and Chiba

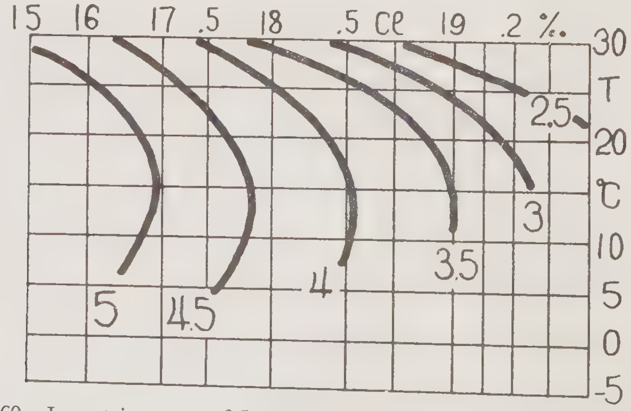

Fig. 60. Isometric curves of *Leptocylindrus danicus* showing the change in the number of indiviuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(1954) from the Aleutian region. BODEN (1949), TSUBATA (1950), MARUMO (1953a, b, 1957) all agree that it is absent from the Antarctic.

From those records, it may be taken for granted that *danicus* deserves the name of neritic, wide-spread species. SMAYDA (1958) regarded *danicus* together with *Skeletonema costatum* and *Thalassionema nitzschioides* as cosmopolitan. However, quantitative variations according to the change of both temperature and chlorinity shown in Fig. 60 are, neverthless, relatively characteristic of the present species.

(17) *Nitzschia delicatissima.* (Fig. 61)

Data were taken from Kobe Marine Observatory (1955–1958). Similarly to *L. danicus*, *Nitzschia delicatissima* is broadly distributing and is very little affected by temperature. Decrease in quantity in warm water with high chlorinity, however, is slightly larger than in *danicus*. As maintained by CUPP (1943), *delicatissima* is neritic and wide-spread species, though it was regarded by KOKUBO (1955) as belonging to a cold water form.

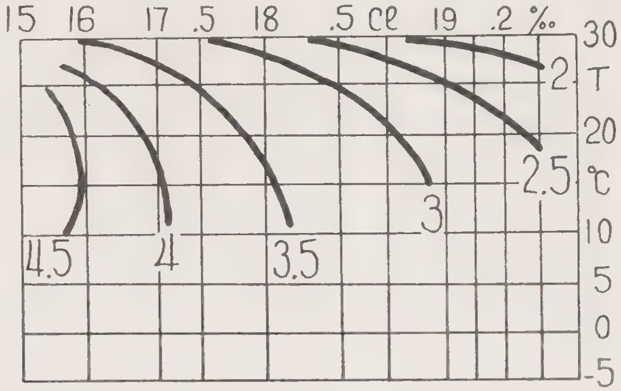

Fig. 61. Isometric curves of *Nitzschia delicatissima* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(18) *Nitzschia seriata.* (Fig. 62)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (1930–1941). Among the species here enumerated *Nitzschia seriata* is one of the species most widely distributed. In warmer waters decrease in quantity is conspicuous irrespective of the change of chlorinity, so long as this lies between 15–19.4 Cl ‰. At a temperature lower than 5°C the decrease caused by the fall of temperature is also distinct. GRAN (1908) considered this species as an arctic and oceanic one, but CUPP (1943) was of the opinion that it belongs to a neritic species, distribution of which extends from the northern temperate to the arctic seas. The species is found in a large concentration in the water with the very low temperature

of -1°C in the Antarctic (MARUMO 1953). On the contrary, many of the workers have collected this diatom in the tropical Pacific, such as in the Palao Lagoon (TOKIOKA 1942), around the Marshall Islands (KITOU 1952) and in the Truck Lagoon (MARUMO 1954). SHIMOMURA (1953a) said the optimum temperature for this species lies around 15°C. It appears to the author more reasonable to regard it as a widespread species, as KOKUBO (1955) assumes.

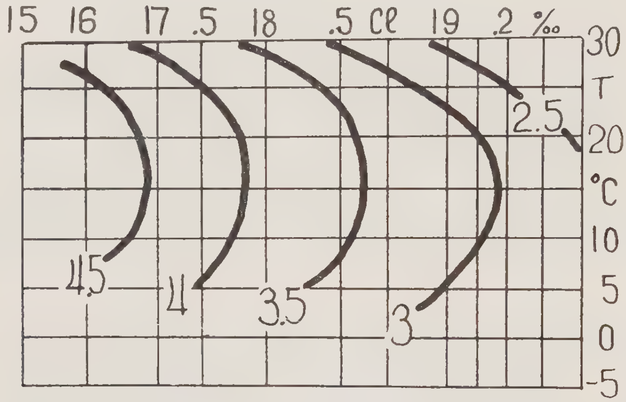

Fig. 62. Isometric curves of *Nitzschia seriata* showing the change in the number of individuals according to the various cominations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(19) *Rhizosolenia bergonii.* (Fig. 63)

Data were taken from Kobe Marine Observatory (1955–1958). The graph inserted here (Fig. 63) is certainly unreliable in the region lower than 18.51 Cl‰ in chlorinity and lower than 15°C in temperature, because of the small appearing fre-

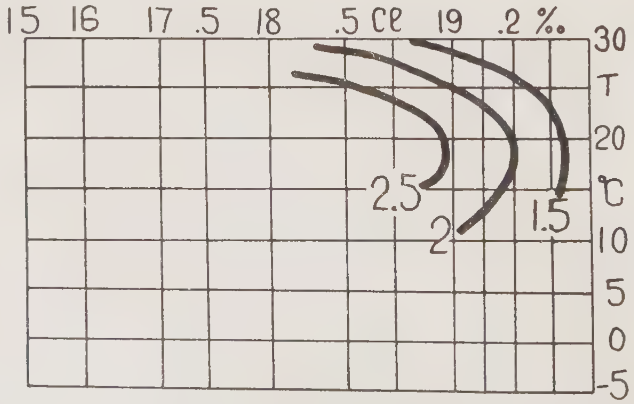

Fig. 63. Isometric curves of *Rhizosolenia bergonii* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

quency. Being an oceanic, warm water species, *Rhizosolenia bergonii* is most abundant in water having a temperature of about 20°C and a chlorinity of about 18.5 Cl‰. Neverthless, the quantity of the species is strongly reduced in the warmest and most haline region of the graph. Cupp (1943) regarded the species as an oceanic south-temperate or subtropical species. It is relatively common in the tropical Pacific, such as Palao Lagoon (Tokioka 1942) and the neighbouring seas of the Marshall Islands (Kitou 1952).

(20) *Rhizosolenia setigera.* (Fig. 64)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (1931–1940). *Rhizosolenia setigera* is relatively common in its occurrence and is most abundantly found in the seas with a temperature of 10°–15°C and with a chlorinity of about 16 Cl ‰ or less. Its quantity decreases decidedly from a temperature of 17.°5C upward and from 10°C downward. From this fact, the species can be regarded as neritic, north temperate species, as Cupp (1943) presumed. Hustedt (1934) and Kokubo (1955) held the species to be eurythermal and euryhaline. This diatom is found in the Palao Lagoon (Tokioka 1942), but neither in the Antarctic Ocean (Boden 1949, Tsubata 1950, Marumo 1953a, b), nor in the extreme northern part of the North Pacific (Karohji 1958). Accordingly, it is considered as being incapable of withstanding such cold water. The range of the endurable temperature is not so broad as in other eurythermal species, e. g. *C. affinis* and *L. danicus*. As to the lowest salinity which the present species can bear, Smayda (1958) said it lies between 7 and 15 ‰ (4 and 8 Cl ‰ in chlorinity).

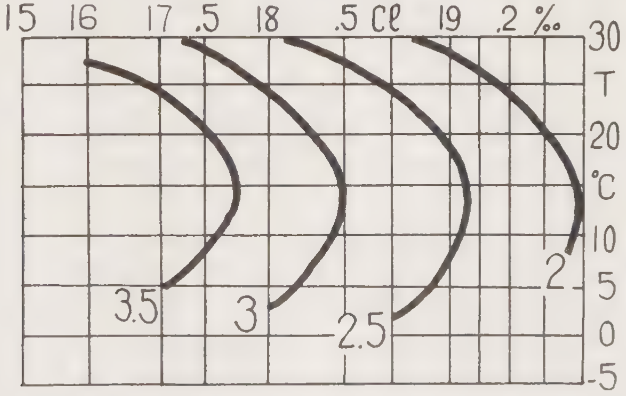

Fig. 64. Isometric curves of *Rhizosolenia setigera* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(21) *Rhizosolenia stolterfothii.* (Fig. 65)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (1931–1940). This species occurs under every combination of temperature

and chlorinity, in so far as these are confined within the range dealt with here. It is most abundant at a high temperature at 15°–20°C and in a chlorinity of 17.5–18.5 Cl ‰. Gradient of quantity is large against the change of both temperature and chlorinity. Shimomura (1953a), in his observation on the course from Tokyo to Hachijyo-jima, stated that the species is confined in its distribution to the water with temperatures of 10°C or more and with chlorinities of 17 Cl ‰ or more and it prefers the temperature range of 20° to 25°C. It is known from the south-west of Australia in waters having temperatures between 9°–19°C (Marumo 1957), but unknown from the Antarctic Ocean (Boden 1949, Tsubata 1950, Marumo 1953a, b, 1957). Although the species is in general assumed to be a neritic inhabitant (Cupp 1943, Hustedt 1930), it may be oceanic to some extent, as in Cupp's (1943) statement that it is "sometimes regarded as oceanic". It is usually assigned to eurythermal type, and yet the isometric curves inserted here show that it ought to be looked upon preferably as stenothermal.

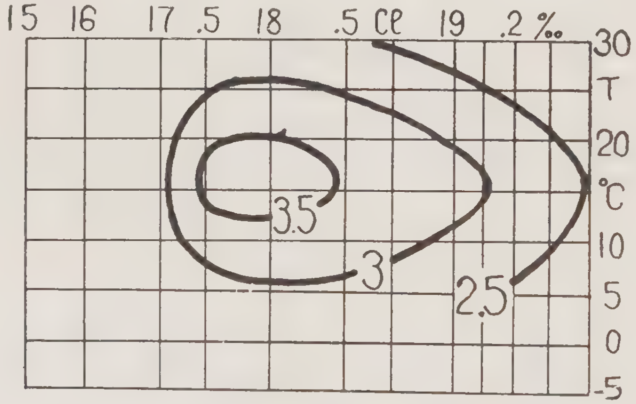

Fig. 65. Isometric curves of *Rhizosolenia stolterfothii* showing the change in the number of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(22) *Rhizosolenia styliformis*. (Fig. 66)

Data were taken from Kobe Marine Observatory (1955–1958). This species is very similar to *R. stolterfothii* in the feature of quantitative change according to temperature and chlorinity. Range of temperature in which the species can live seems somewhat broader than in *stolterfothii* and that of chlorinity is slightly lower. The species is common in the Antarctic (Boden 1949, Tsubata 1950, Marumo 1953b, 1957) and it frequently appears monotonously in waters with temperatures of 2.°0 to 4.°0C (Marumo 1953b, 1957). Shimomura (1953a) recorded the maximum occurrence (368 cells/L) in the Antarctic in water with temperature of −3°C and with chlorinity of 18.58 Cl ‰. From the North Pacific and the Bering Sea the species has been recorded only twice (Takano 1959 and Cupp 1937). This fact suggests that it occurs in cold waters only in a relatively small quantity. Accordingly, when the total cell

number of all the appearing diatoms is large, the frequency of the appearance of this species is small. The lower limit of the endurable salinity was reported by SMAYDA (1958) to lie between 7 and 15 ‰ (4 and 8 Cl ‰ in chlorinity). The species was designated by CUPP (1943) and HUSTEDT (1930) to oceanic, north temperate form.

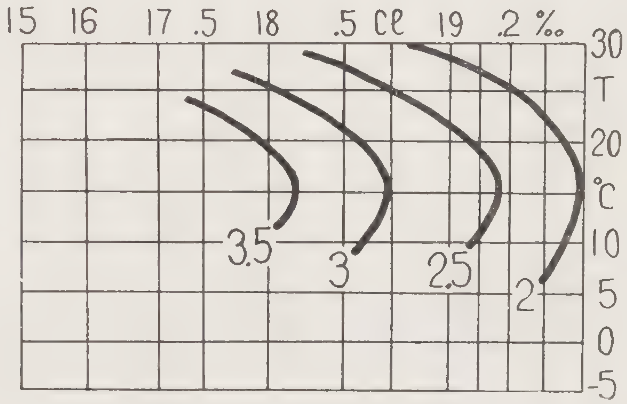

Fig. 66. Isometric curves of *Rhizosolenia styliformis* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(23) *Skeletonema costatum.* (Fg. 67)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (KOKUBO 1931–1940). Of all the species dealt with in this paper, *Skeletonema costatum* is most characteristic in the abundance of its quantity and in the broadness of the range of temperature and chlorinity, in which it is prevailing. It occurs most abundantly in the temperature range of 10°–20°C and at a chlorinity lower than 15 Cl ‰. In Osaka Bay, the range of chlorinity most abundant with this species extends from 14.0 to 15.0 Cl ‰ and is narrower than the optimum one recorded by MATSUE (1954) in his culturing experiment (UYENO 1957c, 1957d; c.f. chapter I-(1)). Decrease in quantity of the species associated with the rise or fall of temperature becomes more distinct from 25°C upward, or from 10°C downward. Change of quantity against that of chlorinity is rather large. In warm waters with high chlorinities the quantity is very small, or reduced to zero. Occurrence of the species extends from arctic to tropical waters, though unknown from the Antarctic. In the tropical Pacific, MARUMO (1954) recorded it from the Truck Lagoon. In her survey made at Scotch Cap in each summer season of 1926–1933, CUPP (1937) observed an abundant occurrence at a temperature from 7° to 10°C. This range of temperature corresponds to the lower limit of the temperature in Fig. 67 in which the species occurs in the largest number. SHIMOMURA (1953a), in his observations made on the course from Tokyo to Hachijyo-jima, stated that the species occurs at the temperature range of 9° to 24°C, becoming extinct at temperature higher than

25°C. In the other observation (Shimomura 1953 b) made along the coast from Tokyo to Hakodate, he further said that the seas with temperatures lower than 8°C and destitute of the species and the areas of its main distribution are in the temperature ranges from 10° to 15°C and the chlorinity is from 18.6 to 19.0 Cl ‰.

Smayda (1958) regarded the species together with *Leptocylindrus danicus* and *Thalassionema nitzschioides* as cosmopolitan. For this reason, *Skeletonema costatum* is generally regarded as unworthy of the indicator of water masses. Its quantitative distribution illustrated here, however, clearly shows that as one of the finest indicator species it deserves more attention in analyzing the mixing process of the coastal water with the oceanic.

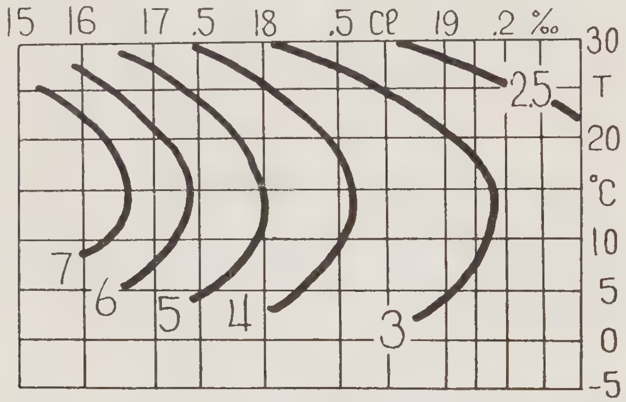

Fig. 67. Isometric curves of *Skeletonama costatum* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(24) *Thalassiothrix frauenfeldii.* (Fig. 68)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (1931–1940). The species is most abundant at a temperature of 15°–20°C and in a chlorinity of 17.5 Cl ‰ or less. The range of optimum temperature is higher than that of all the species here dealt with and covers the highest part of the graph. The range of chlorinity lies midway between that of neritic species and that of oceanic species. Outside the range in which the species is abundant, decrease in quantity due to rise or fall of temperature is rather gradual and even at the highest temperature and chlorinity it is still present in a certain quantity. The species never occurs in cold waters, such as in the surrounding of the Aleutians (Cupp 1937, Motoda and Kawarada 1955 etc.). In the northern coast of Japan, it was recorded by Yamaji (1950, 1951) from Akkeshi and Hakodate, but unrecorded from Yoichi, Nemuro and Hanasaki. It was discovered by Marumo (1954) in the sea off Kinkazan in winter and by Kokubo (1931–1940) at Asamushi. *Thalassiothrix frauenfeldii* was looked upon by Cupp (1943) as a neritic, warm water, widespread species. It is rather difficult to draw any conclusion as to whether it represents neritic or

oceanic species, since the isometric curves show the characteristics of both. If anything, the neritic color is slightly predominant.

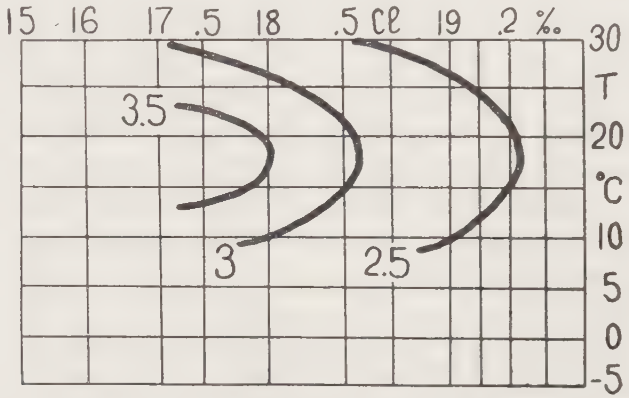

Fig. 68. Isometric curves of *Thalassiothrix frauenfeldii* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10 L. Abbreviations as in Fig. 13.

(25) *Thalassionema nitzschioides.* (Fig. 69)

Data were taken from Kobe Marine Observatory (1955–1958) and Plankton Journal (1931–1940). Similarly to *Nitzschia seriata*, *Thalassionema nitzschioides* is the most widely distributed species. The temperatures at which the species is most abundantly found ranges from −5° to 25°C. Decrease in quantity is noticeable from the temperature of 25°C upward, although unrecognizable in a lower temperature. Showing a large gradient also against chlorinity, the quantity of the species is strongly reduced at a higher temperature and at higher chlorinity. In Osaka Bay, the species is scarcely found at a chlorinity below 15 Cl ‰, while it flourishes most in the range of 15–16 Cl ‰ (Uyeno 1957 b, 1957 c, 1957 d). Owing to the scantiness of the materials obtained, the decrease in quantity at a lower chlorinity is not perceptible from the curves inserted here.

In the sea lying between Tokyo and Hachijyo-jima, Shimomura (1953 a) recorded a maximal occurrence of the species at a temperature of about 25°C and at a chlorinity lower than 19 Cl ‰. In another report on his observations made in the seas between Tokyo and Hakodate (Shimomura 1953 b), he said that the optimum temperature extends from 9° to 15°C and the optimum chlorinity lies between 18.5 and 19.0 Cl ‰. In the tropics, the species occurs at the inlet of the Palao Lagoon (Tokioka 1942), but not in the open ocean (Kitou 1952, Marumo 1954). In the Arctic it is mainly found in the neritic region (Takano 1959). It was recorded from the western part of the Aleutian waters by Motoda and Kawarada (1955) and Takano (1955), from Scotch Cap, the eastern Aleutians by Cupp (1937) and from the Bering Sea by Marumo (1956). In the Antarctic it is unrecorded (Boden 1949, Tsubata 1950 and Marumo 1953 a, b). From these records, it is presumed that the

isometric curves shown in Fig. 69 turning to the left at a temperature lower than 5°C clearly indicate the characteristic nature of this species.

Smayda (1958), who dealt with the qualitative analysis of the temperature-salinity relation in *Thalassionema nitzschioides*, stated that the range of temperature in which the species is viable lies between −3° to 30°C and the ranges of salinity lies between 0 to 40 ‰. From the distribution records of this species in relation to temperature and salinity, he concluded that this is eurythermal and euryhaline. The characteristics of the isometric curves inserted here, however, appear to tell that his conclusion is untenable. Cupp (1943) believed the species to be a north temperate one, but it may more adequately be assigned to a cosmopolitan form, as Hustedt (1932) and Kokubo (1955) claimed.

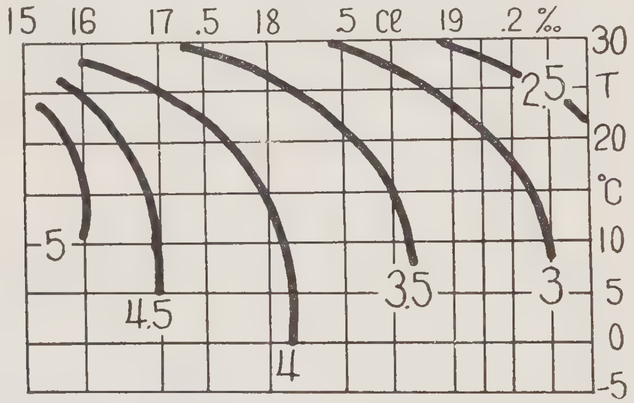

Fig. 69. Isometric curves of *Thalassionema nitzschioides* showing the change in the number of individuals according to the various combinations of temperature and chlorinity. Number of individuals are represented by log cell number/10. L. Abbreviations as in Fig. 13.

VI. Summary

(1) The aim of the present study, which is the summarization of the author's works carried out since 1957, consisted in ascertaining the relations which may exist between the distribution of diatoms and the various combinations of temperature and chlorinity in the sea.

(2) The observation carried out in Osaka Bay on five diatom communities composed of different species clearly indicated the presence of a definite correlation between the distribution of each diatom community and the chlorinity of bay water. Each community is determined in its range almost exactly by the gradient of chlorinity in the bay, although it is also controlled under certain circumstances by temperature.

(3) There is no intimate relation between the composition of diatom species and the gradient of temperature and chlorinity in the region ranging from inshore off Shionomisaki to offshore beyond the Kuroshio. The total population, however,

varies in quantity with the increase of the horizontal mixing of water, so that the quantity of total diatoms more effectively serves as a good indicator in determining the range of the Kuroshio than the species composition.

(4) The observations made in the region off Enshu-nada, where the upwelling of cold water occurs, lead to the conclusion that the pattern of horizontal and vertical distributions of the diatom population is very effectively dependent on such a movement of water as divergence, or convergence.

(5) A method for representing the quantitative occurrence of diatoms at each combination of temperature and chlorinity of the water is proposed by means of isometric curves drawn on the diagrams. A comparison the result by this method with that of the actual observations shows that there is a fair coincidence between these two results on the seasonal fluctuation of diatom quantity, at least, in the case of Husan Harbor. The result of the theoretical calculation proposed by RILEY and VON ARX (1949) also fairly coincides with the result of the present method.

(6) The rôle of temperature and chlorinity in the circulation of organic matters in the sea is discussed and illustrated diagramatically.

(7) The seasonal change in diatom quantity and in temperature and chlorinity is discussed by adopting the above mentioned isometric curves of diatom occurrence. From the quantitative appearance of diatoms the neighbouring seas of Japan are divisible into three types: north temperate, south temperate and subtropical. Productivity on the coasts around Japan are estimated from the monthly mean of temperature and chlorinity.

(8) From the practical point of view, suitability of the inshore waters to the cultivation of pearl oyster (*Pteria* (*Pinctada*) *martensii*) is discussed on the basis of the primary production of the water and also of the temperature cycle, which are derived from the analysis of the proposed method.

(9) Preference of temperature and chlorinity in twenty-five dominant diatom species occurring in the neighbouring seas of Japan is explained by adopting the present proposed method. By means of this more accurate knowledge is given concerning the distribution of each species in relation to temperature and chlorinity.

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Regional Differences in the Composition of Fouling Communities in Ago Bay

By

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In one of my previous works I made a study on the vertical differences in the composition of the fouling communities in a definite point in Ago Bay. The present report deals with the differences among a number of stations taken within the bounds of the Bay. It may provide us with a certain suggestion in determining the relation between the community and the condition of pearl oyster farms which are built throughout the Bay.

Regional differences of the fouling communities within a restricted area have ever been studied by several authors either with test surfaces (CORLETT, 1948; EDMONDSON, 1944; GUNTER & GEYER, 1955; WEISS, 1948), or with fixed floating constructions, such as, buoys or light-ships (CORLETT, 1948; FRASER, 1938; KIRCHENPAUER, 1862; MILNE, 1940; Woods Hole Oceanogr. Inst., 1952). As the studies which have been made with test surfaces have treated the comparison among only a small number of stations, the present study discusses the matter taking as many stations as possible.

I am indebted to the Authorities of Mie Prefecture for a grant from the fund for the research of pearl oyster culture. Thanks are also extended to Mr. K. TAKAYAMA, Director of National Pearl Research Laboratory, for supplying various facilities in making my work at Tatoku Marine Station of the Laboratory, and to Ise Branch of the Pearl Research Association for the permission of publishing the various data on the environmental factors. My grateful acknowledgement is, further, due to Prof. S.M. SHIINO, Dean of our Faculty, for his criticizing and correcting the manuscript.

I. Method

The concrete test blocks (20cm × 20cm × 1.5cm) suspended in the sea 2m below the surface were immersed in the sea water for four months (119 days) ranging from June 18 to October 15, 1958. The blocks with attached animals were transported to Tatoku Marine Station from each locality and photographed there prior to their preservation in formalin. They were soon brought to our University so as to be placed under detailed examination.

Ten stations selected within the bounds of Ago Bay were: (1) Hunakosi, (2)

Katada, (3) Huseda, (4) Wagu, (5) Sin-Nakiri, (6) Tategami, (7) Masaki, (8) Ugata, (9) Hamazima and (10) Goza (Fig. 1). At the last of these stations, the collection of material on the appointed date was made impossible on account of violent waves caused by stormy weather. An accurate measurement of Hamazima material was not taken because of too rapid development of the community there. The comparison of the communities was, accordingly, made among the stations exclusive of these two.

II. Locality

Ago Bay is embraced by a narrow peninsula on the east and south sides, opening to the Pacific on the west side. To the north and not far from the Bay there lies Matoya Bay. Owing to such a topographic condition river rarely flows into Ago Bay, inner part of which, however, possesses many inlets complicatedly invading the land. The stations named above are selected so that they cover the recesses of three main inlets as well as the central part of the Bay. From the first of these inlets Hunakosi, Katada and Huseda are taken, from the second Sin-Nakiri and

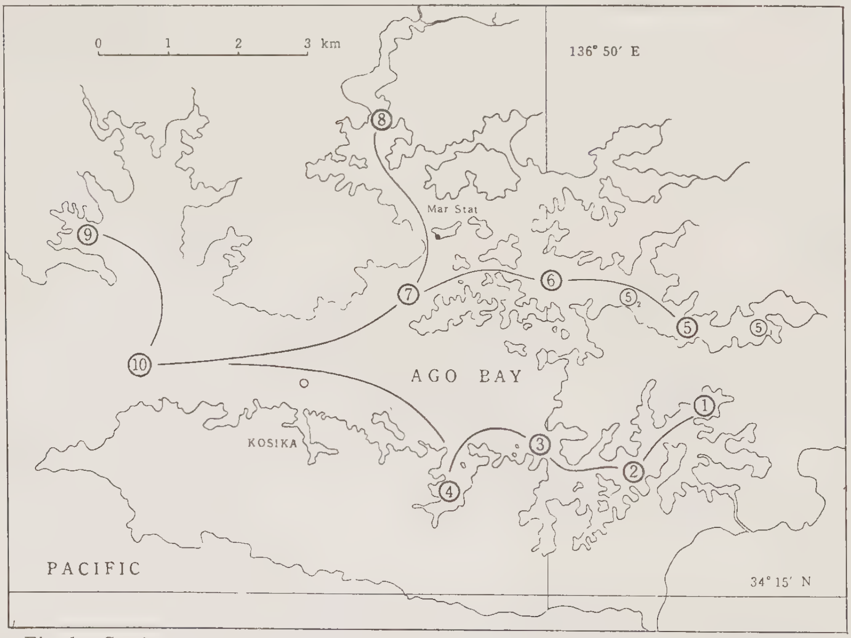

Fig. 1. Stations of experiment in Ago Bay. 1, Hunakosi; 2, Katada; 3, Huseda; 4, Wagu; 5, Sin-Nakiri (5_1, 5_2, for the first and the second months of experiment); 6, Tategami; 7, Masaki; 8, Ugata; 9, Hamazima; 10, Goza.

Tategami, and from the third Ugata. Wagu and Masaki lie in the central region of the Bay, the former locating near the entrance of the first inlet and the latter near that of the second and third.

In these recesses, the water is scarcely renewed and the temperature rises

high in summer (Table 1). Since the pearl oysters are cultivated even there, organic matter emitted from them is gradually accumulated in the shoal of the narrow recesses. Water pollution caused by the decay of the organic matter, in turn,

Table 1.

Environmental factors represented by the average of specific gravity σ [$\sigma = (\rho - 1) \times 1000$] (upper column) and that of water temperature °C (lower column) at the depth of 2m. F., S., the first and the second halves of month. Rainfall at Kosika.

		Rainfall	Hunakosi	Katada	Huseda	Wagu	(Kosika)	Goza	Ugata	Masaki	Hamazima
June	S.	little	23.67 24.0	24.40 24.5	23.88 23.9	23.52 23.9	23.63 23.5	— —	17.58 25.0	— —	23.96 24.3
July	F.	little	23.51 25.3	— —	23.70 25.1	— —	23.87 24.8	— —	17.55 26.2	— —	24.37 24.8
	S.	little	23.47 25.8	— —	23.56 26.3	23.88 26.0	23.62 25.2	24.56 25.0	16.31 27.2	24.35 26.5	24.61 25.4
August	F.	little	23.27 28.2	23.70 28.0	23.45 27.8	23.69 27.6	23.35 26.3	24.31 25.4	17.73 28.4	24.21 27.8	23.89 27.0
	S.	100mm	23.97 28.8	23.30 28.4	23.06 27.6	— —	23.45 26.5	24.38 25.8	16.94 28.1	23.87 27.9	23.84 27.0
September	F.	little	— —	21.40 28.3	22.26 28.1	— —	21.63 27.0	22.68 26.0	— —	22.17 27.2	21.66 27.0
	S.	200mm	22.23 25.6	20.00 24.9	22.35 24.4	— —	22.05 24.4	23.62 24.0	16.82 24.6	23.48 24.1	23.02 24.6
October	F.	70mm	— —	21.70 21.6	22.71 22.3	— —	23.38 21.8	— —	— —	23.78 22.1	23.69 21.7

results in a serious deficiency in dissolved oxygen. Under these circumstances, at Sin-Nakiri the place of experiment was forced to be moved twice during the whole course (Fig. 1).

III. Frequency of animals

Animals appearing on the test blocks amount 26 species in all, comprising 2 spp. of Porifera, 10 spp. of Bryozoa, 4 spp. of Pelecypoda, 5 spp. of Polychaeta and 5 spp. of Cirripedia. The numbers of their individuals or of their colonies are listed in Table 2. Among those species, *Spirorbis foraminosus*, *Hydroides norvegica*, *Balanus amphitrite communis*, *Watersipora cucullata* and *Brachidontes senhousia* are most abundantly found, decreasing in number in due order. Square roots of the numbers, on the basis of which Fig. 2 is drawn, are also shown in the Table.

Although *Spirorbis foraminosus* is most frequently met with, it is inadequate to draw a comparison between this species and any one of others with respect to their occurring number, for the species was reduced during the succession in some communities, as for example, in those at Wagu and Masaki.

Hydroides norvegica numbers 252 at Hunakosi, 97 at Katada, 42 at Huseda and

92 at Wagu. In the first inlet, therefore, the number decreases from the recesses toward the central region of the Bay. A similar tendency is perceptible in the second inlet, in which the species numbers 514 at Sin-Nakiri (recesses), 487 at Tategami and 119 at Masaki (central region). At Ugata in the third inlet the species is found in greater number (203) than at Masaki (119).

Table 2.

Frequency of animals found within the area of 20cm × 20cm (upper column) and their square roots (lower column).

	Huna-kosi	Katada	Huseda	Wagu	Sin-Nakiri	Tate-gami	Masaki	Ugata
PORIFERA								
1. *Scypha sp.*	0	0	0	0	0	0	1 1.00	0
2. *Reniera sp.*	0	0	0	4 2.00	0	0	0	0
BRYOZOA								
3. *Watersipora cucullata*	0	43 6.56	37 6.08	57 7.55	56 7.48	108 10.39	52 7.21	48 6.93
4. *Schizoporella unicornis*	0	0	0	1 1.00	0	0	0	0
5. *Siniopelta costazii*	0	10 3.16	0	11 3.32	0	10 3.16	10 3.16	5 2.24
6. *Holoporella sp.* (?)	0	0	0	18 4.24	0	0	0	0
7. *Electra angulata*	0	0	0	2 1.14	0	3 1.73	1 1.00	1 1.00
8. *Bugula neritina*	0	0	0	1 1.00	3 1.73	4 2.00	2 1.41	9 3.00
9. *Tricellaria occidentalis*	0	0	0	0	0	0	1 1.00	0
10. *Idomonea sp.**	0	1 1.00	0	6 2.45	0	7 2.65	0	0
11. *Lichenopora imperialis**	0	0	0	0	0	0	0	1 1.00
12. *Bowerbankia imbricata***	0	0	0	0	0	0	2 1.41	0
PELECYPODA								
13. *Crassostrea gigas*	10 3.16	2 1.41	5 2.24	29 5.39	2 1.41	3 1.73	1 1.00	4 2.00
14. *Pinctada martensii*	0	2 1.41	0	1 1.00	0	0	2 1.41	1 1.00
15. *Brachidontes senhousia*	2 1.41	1 1.00	1 1.00	14 3.74	0	0	0	336 18.33
16. *Volsella trailli*	1 1.00	0	1 1.00	10 3.16	0	3 1.73	0	3 1.73
POLYCHAETA								
17. *Spirorbis foraminosus*	7,216 84.95	9,408 96.99	9,344 96.66	11,344 106.49	12,464 111.62	9,246 96.16	1,760 41.95	4,112 64.12
18. *Hydroides norvegica*	252 15.87	97 9.85	42 6.84	92 9.59	514 22.67	487 22.07	119 10.91	203 14.25
19. *Serpula sp.* (?)	14 3.87	0	0	6 2.45	18 4.24	2 1.41	7 2.65	1 1.00

20. *Spirobranchus giganteus*	0	0	0	2 1.41	0	1 1.00	3 1.73	0
21. *Pomatoleios crosslandi*	0	0	0	1 1.00	20 4.47	0	0	0
CIRRIPEDIA								
22. *Balanus amphitrite communis*	0	25 5.00	2 1.41	746 27.31	4 2.00	40 6.32	751 27.40	41 6.40
23. *Bal. amphitrite hawaiiensis*	0	0	0	2 1.41	3 1.73	1 1.00	0	2 1.41
24. *Bal. amphitrite albicostatus*	0	0	0	1 1.00	0	0	0	0
25. *Bal. improvisus***	0	0	0	0	0	0	1 1.00	0
26. *Bal. trigonus*	0	0	0	0	0	0	4 2.00	0
Total including *Spirorbis*	7,495	9,589	9,432	12,348	13,084	9,933	2,717	4,774
Total excluding *Spirorbis*	279	181	88	1,004	620	669	957	663

* I am indebted to Dr. S. Mawatari for the identification.

** I am indebted to Dr. H. Utinomi for the identification.

Reverse is the case with *Balanus amphitrite communis*. This is scarcely found at Sin-Nakiri (4) (recesses), but increases at Tategami (40), reaching the largest number at Masaki (751) (central region). In the first inlet, the species is 0 at Hunakosi, 25 at Katada, 2 at Huseda and 746 at Wagu. If we take the situation of Huseda into account, it is extraordinary that the occurrence is rather rare there. Nevertheless, the general tendency of the increase is the same as in the second inlet. In the recesses of the third inlet (Ugata (41)) the number is smaller as compared with that at Masaki (751) in the central part.

Watersipora cucullata is abundant in the middle region of the second inlet (Tategami), but absent in the recesses of the first inlet (Hunakosi). It does not show any perceptible difference among the rest five stations in its number.

Brachidontes senhousia forms a goodly number only in the recesses of the third inlet (Ugata).

IV. Constitution of communities

Constitution of a community may be deducible from the calculation of the percentage of each occurring species to the total. The results of the calculation are represented in Table 3 for each of the communities at the eight stations. As may be seen from the Table *Spirorbis foraminosus* predominates over other species at all the stations.

At each station the community is more or less advanced in its stage owing to its prolonged submergence in water ranging four months. *Spirorbis* population is reduced in some measure at Wagu and Masaki on account of the rapid advancement of succession. It is, therefore, inappropriate to follow the same procedure in *Spirorbis* as in other species in examining the frequency of occurrence. For this

reason, in calculating the percentage of species the frequency of *Spirorbis* has been excluded from the total (Table 3). If such a precaution is taken, the dominant

Fig. 2. Frequency of animals. Ordinates correspond to the diameters of the circles, areas of which represent the number. 1–8, as in Fig. 1.

species which attain 10% or more in any of the eight communities are *Hydroides norvegica*, *Balanus amphitrite communis*, *Watersipora cucullata* and *Brachidontes senhousia*.

Hydroides norvegica is the most dominant at Hunakosi (90.3%) in the first inlet, but less so at Katada (53.6%) and Huseda (47.7%). In the second inlet, it is dominant at Sin-Nakiri (82.9%) and at Tategami (72.8%). The species, therefore, shows greater preponderance in the more inner regions in both the first and the second inlets.

Balanus amphitrite communis predominates all over others at Masaki (78.5%) and Wagu (74.3%), both of which are located in the central region of the Bay. In other stations, the species is mostly inferior to *Watersipora cucullata* and others in its number, occupying the ranks ranging from the third to the fifth in the order of dominancy. More decisively, it occupies the fourth rank at Huseda (2.3%) and the third

Table 3.

Constitution of communities represented by the percentage of the number to the total exclusive of *Spirorbis*, percentage of which is shown in parenthesis. er., bl., en., erecting, block and encrusting forms.
◎, tall, voluminous or large.

	%	er.	bl.	en.
1. HUNAKOSI	%	er.	bl.	en.
1. *Spirorbis foraminosus*	(96.2)		(○)	
2. *Hydroides norvegica*	90.3		○	
3. *Serpula sp.* (?)	5.0		○	
4. *Crassostrea gigas*	3.6		◎	
5. *Brachidontes senhousia*	0.7		○	
6. *Volsella trailli*	0.4		○	
Total	100.0	0.0	100.0	0.0
2. KATADA	%	er.	bl.	en.
1. *Spirorbis foraminosus*	(97.7)		(○)	
2. *Hydroides norvegica*	53.6		○	
3. *Watersipora cucullata*	23.7			◎
4. *Balanus amphitrite communis*	13.8		◎	
5. *Siniopelta costazii*	5.5		○	
6. *Crassostrea gigas*	1.1		◎	
7. *Pinctada martensii*	1.1		◎	
8. *Idomonea sp.*	0.6		○	
9. *Brachidontes senhousia*	0.6		○	
Total	100.0	0.0	76.3	23.7
3. HUSEDA	%	er.	bl.	en.
1. *Spirorbis foraminosus*	(99.0)		(○)	
2. *Hydroides norvegica*	47.7		○	
3. *Watersipora cucullata*	42.1			◎
4. *Crassostrea gigas*	5.7		◎	
5. *Balanus amphitrite communis*	2.3		◎	
6. *Brachidontes senhousia*	1.1		○	
7. *Volsella trailli*	1.1		○	
Total	100.0	0.0	57.9	42.1
4. WAGU	%	er.	bl.	en.
1. *Spirorbis foraminosus*	(92.1)		(○)	

2. *Balanus amphitrite communis*	74.3		◎	
3. *Hydroides norvegica*	9.1		○	
4. *Watersipora cucullata*	5.7			◎
5. *Crassostrea gigas*	2.9		◎	
6. *Holoporella sp.* (?)	1.8			○
7. *Brachidontes senhousia*	1.4		○	
8. *Siniopelta costazii*	1.1		○	
9. *Volsella trailli*	1.0		○	
10. *Serpula sp.* (?)	0.6		○	
11. *Idomonea sp.*	0.6		○	
12. *Reniera sp.*	0.4			◎
13. *Electra angulata*	0.2			◎
14. *Spirobranchus giganteus*	0.2		○	
15. *Balanus amphitrite hawaiiensis*	0.2		◎	
16. *Schizoporella unicornis*	0.1			◎
17. *Bugula neritina*	0.1	◎		
18. *Pinctada martensii*	0.1		◎	
19. *Pomatoleios crosslandi*	0.1		○	
20. *Balanus amphitrite albicostatus*	0.1		◎	
Total	100.0	0.1	91.7	8.2
5. SIN-NAKIRI	%	er.	bl.	en.
1. *Spirorbis foraminosus*	(95.1)		(○)	
2. *Hydroides norvegica*	82.9		○	
3. *Watersipora cucullata*	9.0			◎
4. *Pomatoleios crosslandi*	3.3		○	
5. *Serpula sp.* (?)	2.9		○	
6. *Balanus amphitrite communis*	0.6		◎	
7. *Balanus amphitrite hawaiiensis*	0.5		◎	
8. *Bugula neritina*	0.5	○		
9. *Crassostrea gigas*	0.3		◎	
Total	100.0	0.5	90.5	9.0
6. TATEGAMI	%	er.	bl.	en.
1. *Spirorbis foraminosus*	(93.2)		(○)	
2. *Hydroides norvegica*	72.8		○	
3. *Watersipora cucullata*	16.2			◎
4. *Balanus amphitrite communis*	6.0		◎	
5. *Siniopelta costazii*	1.5		○	
6. *Idomonea sp.*	1.1		○	
7. *Bugula neritina*	0.6	◎		
8. *Electra angulata*	0.4			◎
9. *Crassostrea gigas*	0.4		◎	
10. *Volsella trailli*	0.4		○	
11. *Serpula sp.* (?)	0.3		○	
12. *Balanus trigonus*	0.15		◎	
13. *Spirobranchus giganteus*	0.15		○	
Total	100.0	0.6	82.8	16.6
7. MASAKI	%	er.	bl.	en.
1. *Spirorbis foraminosus*	(64.5)		(○)	
2. *Balanus amphitrite communis*	78.5		◎	

3. *Hydroides norvegica*	12.5		○	
4. *Watersipora cucullata*	5.4			◎
5. *Siniopelta costazii*	1.1		○	
6. *Serpula sp.* (?)	0.7		○	
7. *Balanus trigonus*	0.4		◎	
8. *Spirobranchus giganteus*	0.3		○	
9. *Bowerbankia imbricata*	0.2	◎		
10. *Bugula neritina*	0.2	◎		
11. *Pinctada martensii*	0.2		◎	
12. *Scypha sp.*	0.1	○		
13. *Electra angulata*	0.1			◎
14. *Tricellaria occidentalis*	0.1	◎		
15. *Crassostrea gigas*	0.1		◎	
16. *Balanus improvisus*	0.1		◎	
Total	100.0	0.6	93.9	5.5
8. UGATA	%	er.	bl.	en.
1. *Spirorbis foraminosus*	(86.2)		(○)	
2. *Brachidontes senhousia*	50.6		○	
3. *Hydroides norvegica*	30.6		○	
4. *Watersipora cucullata*	7.2			◎
5. *Balanus amphitrite communis*	6.2		◎	
6. *Bugula neritina*	1.4	◎		
7. *Holoporella sp.* (?)	1.4			○
8. *Siniopelta costazii*	0.8		○	
9. *Crassostrea gigas*	0.6		◎	
10. *Balanus amphitrite hawaiiensis*	0.3		◎	
11. *Volsella trailli*	0.3		○	
12. *Electra angulata*	0.15			◎
13. *Lichenopora imperialis*	0.15		○	
14. *Pinctada martensii*	0.15		◎	
15. *Serpula sp.* (?)	0.15		◎	
Total	100.0	1.4	89.85	8.75

at Katada (13.8%) in the first inlet, the third at Tategami (6.0%) and the fifth at Sin-Nakiri (0.6%) in the second inlet and the fourth at Ugata (6.2%) of the third inlet.

Watersipora cucullata, also showing a high frequency, ranks second at Huseda (42.1%) and at Katada (23.7%) in the first inlet. It ranks as the same class at Tategami (16.2%) in the second inlet, though the percentage is not so high there as in the first inlet. At all the stations except Hunakosi, the species ranks next to *Hydroides norvegica*.

The number of species occurring in a community is 6 at Hunakosi, 9 at Katada, 7 at Huseda and 20 at Wagu in the first inlet, 9 at Sin-Nakiri, 12 at Tategami and 16 at Masaki in the second inlet, and 15 at Ugata in the third inlet (Table 3). In spite of that the number is exceptionally limited at Huseda and enlarged at Ugata, the decreasing tendency of the species number towards the recesses of the Bay may be recognized.

Complexity of a community may be correlative to the abundance of the constituent species as well as to that of the occurring individuals. When all the species are arranged on an abscissa in the order of their abundance which is indicated on an ordinate, the complexity can be represented by a regression line $\log y + ax = b$; where the ordinal of a species is indicated by x, the number of individuals by y and the constants by a and b (Fig. 3).

Angle of inclination which the regression line makes with the abscissa represents the degree of complexity. The smaller the former is, the more complex the latter is, for the difference in the number between the next coming species grows smaller. At Wagu ($a=0.13$) and Masaki ($a=0.18$) in the central part of the Bay, the communities are rather complex in their composition, as this may be perceptible

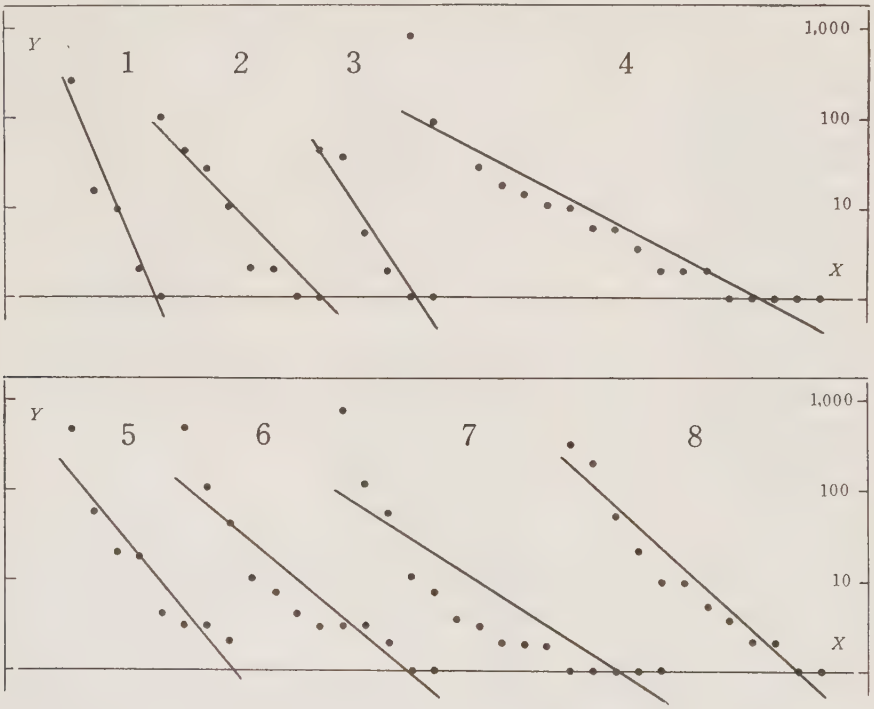

Fig. 3. Complexity of communities represented by regression lines. x, rank of species; y, frequency of animals. 1–8, as in Fig. 1.

from the gentle inclination of the regression lines. On the contrary, in the recesses of the Bay (Hunakosi ($a=0.57$), Sin-Nakiri ($a=0.31$) and Ugata ($a=0.23$)) the composition of the community is more or less simple, as may be seen from the regression lines which make larger angles than in the above-mentioned case. Generally speaking, the more interior a station lies in the Bay, the simpler in its constitution a community is.

V. Communities in advanced stage

In an advanced stage of the development of a community each of the constituting animals takes the life form characteristic to each. The species appearing in

Fig. 4. Diagrammatic representation of communities in the area of 10cm × 10cm. *Spirorbis* is illustrated only in an area 2.5cm × 2.5cm. 2–26, markings of the species, numbers of which are shown in Table 2.

the community can be designated to any of the three principal life forms: erecting, block and encrusting. Communities having developed at eight stations consist prin-

cipally of block forms which are accompanied by a few encrusting ones. Erecting forms such as represented by *Bugula neritina*, *Tricellaria occidentaris*, *Bowerbanchia imbricata*

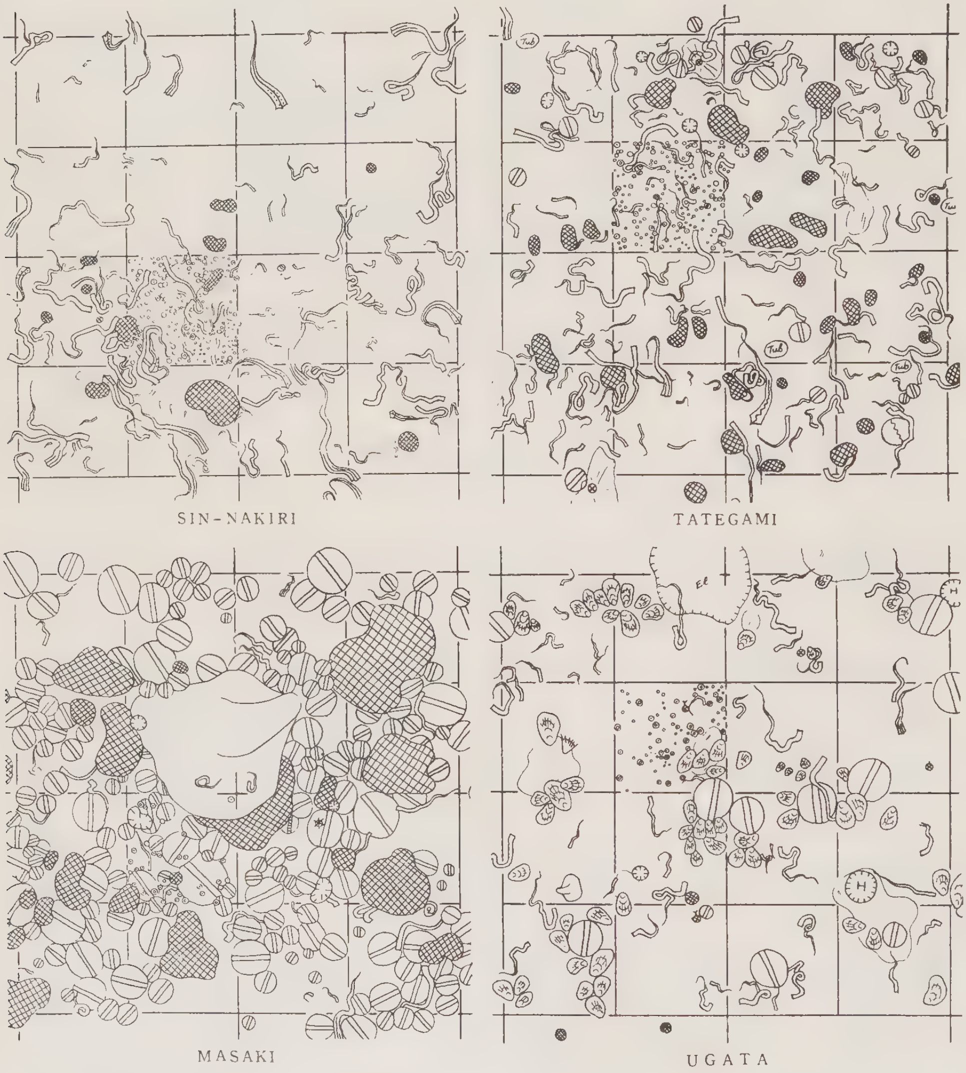

Fig. 5. Same.

and *Scypha sp.* are very scanty, since the season of experiment was inadequate for their growth, especially for the growth of the first two (Table 3).

Of the eight communities, the one at Hunakosi is entirely composed of bolck froms, but the one at Huseda and Katada comprises beside these encrusting forms which occupy a considerable proportion of the whole (42.1% at Huseda and 23.7% at Katada). As the latter forms chiefly comprise *Watersipora cucullata*, the propor-

tion against the former is resulted from the relative abundance of this animal.

Crassostrea gigas and *Balanus amphitrite communis* in block forms and *Watersipora cucullata* in encrusting forms grow into a considerable size. The character of a community is chiefly determined by the number and the extent of the growth of these species (Figs. 4 and 5). The communities at Hunakosi and at Katada in the first inlet are fairly resembling each other in their physiognomy. This is also the case with Sin-Nakiri and Tategami in the second inlet. The two lots of similar communities are again in their part closely resembling between each other in their composition, but those of the second inlet are richer in the number of individuals in comparison with those of the first. This is caused by the abundance of *Hydroides norvegica* and *Watersipora cucullata*, the percentage of which, however, is smaller than in the first inlet. At Sin-Nakiri, *Hydroides norvegica* is accompanied by a multitude of *Pomatoleios crosslandi*, in the presence of which the community is different from that of Tategami.

The development of communities at Wagu and Masaki is again similar to each other in their physiognomy. In both the stations the communities are mainly composed of well-grown *Crassostrea gigas*, *Balanus amphitrite communis* and *Watersipora cucullata*. Of these, *Balanus* is predominant, comprising many individuals of various sizes. Its population at Masaki consists of the individuals larger than at Wagu. This appears to indicate the environment to be more favorable to the growth of *Balanus* at Masaki than at Wagu.

At Ugata in the third inlet, the community abounds in *Brachidontes senhousia*, the presence of which belongs to one of the characteristics of the station. *Balanus amphitrite communis* also makes its appearance in a large number. It appears that the attachment of this animal is restricted to a rather short period, for all the individuals are more or less large in their size. This points to the unfavorableness of the environment to this animal at Ugata.

The community at Huseda is rather peculiar in its aspect due to the excessive scantiness of all the animals except *Spirorbis*, though its composition does not especially differ.

VI. Consideration

Serpulids and Barnacles as prevailing animals:—

Based on his studies in Biscayne Bay, Florida, Weiss (1948) states that the communities at three points in the Bay does not show in the composition of species so much a difference as in the relative numbers among constituent animals. The same is the case with the present study, in which the difference of comparative number between serpulids and barnacles primarily brings about the difference in the appearance of communities.

Contradictory distributions of serpulids and barnacles are noted by several

authors. According to WEISS (1948), a serpulid *Hydroides parvus* dominates on Tahiti Beach, which retreats 6 miles from the head of Biscayne Bay without being affected by tidal current, while barnacles (chiefly consist of *Balanus improvisus*) is prevailing in farther inner region of the Bay at Beach Boat Slips, where the salinity fluctuates regularly in each tidal cycle. EDMONDSON (1944) reports that a barnacle, *Balanus amphitrite hawaiiensis*, is the species most preponderant in the fouling complex at the junction of the east and middle lochs of Pearl Harbor, whereas a serpulid *Hydroides norvegica* is predominant in the vicinity of the coaling dock, which is about two miles nearer the entrance of the Harbor and has a larger depth and a better water circulation. These works show that the barnacle is prevailing in the recesses of the bay rather than the serpulid is.

On the contrary, CORLETT (1948) observes in Liverpool Bay that a deep water barnacle *Balanus hameri* is the commonest of all other animals at the place far from the coast, wheras serpulid worms *Serpula vermicularis* and *Pomatoceros triqueter* dominate near the estuary. Since *Balanus amphitrite communis*, which prevails in the central region of Ago Bay, belongs to a deep water species, the results of the present study is in accord with CORLETT's observation.

Environmental conditions:—

Except for the data obtained at Ugata, there is little difference in the specific gravity of water between the centre of the Bay and its recesses, though it is slightly lower in the latter than in the former. Conformity in specific gravity through all the stations appears to be due to the paucity of rainfall during the experiment and to the topographic condition of the Bay. Temperature of water, higher in the recesses, gradually becomes lower toward the central region. At Sin-Nakiri in the second inlet deficiency of dissolved oxygen is aroused by the decay of organic matter emitted from pearl oyster farms. Water pollution becomes severer toward the innermost shoal of the narrow inlet. Gradual change in temperature, pollution and other environmental conditions to be found from the recesses of an inlet to its head may be originated in the difference in the extent of mixing of inlet water with that of the bay centre. Transition in the constitution of the communities is then attributable to the successive change of environmental conditions.

WEISS (1948), in his studies of Biscayne Bay, points out that the number of animals attached on Gulf Docks, which is almost always swept by ocean water, never attains to that of Beach Boat Slips, which is washed periodically by bay water in each tide. He notices, further, the fact that a moderate contamination of water is favorable for the increase of food supply. The fact that the fouling complex in the central region of Ago Bay, especially at Masaki, vigorously grows may be due to the same reason.

Horizontal difference of communities in comparison with vertical one:—

GUNTER & GEYER (1955), who make a study in the northwest Gulf of Mexico, find the top to bottom distribution of sessile animals to be a miniature of the hori-

zontal one from the estuary to the open sea many miles off the shore. A similar relation is also found in Ago Bay as may be seen from the results of the present study and of the previous one (KAWAHARA & IIZIMA, 1960). Communities from the central part of Ago Bay are more complicated in their composition and more advanced in their development, having *Balanus amphitrite communis* as dominant species. Such a composition is very similar to that found on lower layers in the previous study. On the contrary, the communities from the recesses of the Bay, where *Hydroides norvegica* is predominant and is accompanied by *Watersipora cucullata*, are simpler in their composition and retarded in their development. Communities with similar composition are found on the layers near the surface, as stated in the previous work. In respect of environmental factors in a bay, vertical change found from surface to bottom usually resembles horizontal one extending from estuary to open sea. The above-mentioned variation in the constitution of communities may be due to the change of environmental conditions.

Rèsumé

1) Comparison was made on the communities having developed on the concrete blocks immersed at eight stations in Ago Bay during the course of four months from June 18 to October 15, 1958.

2) Communities from the central part of the bay are more complicated in their composition and more advanced in their developmental stage, having *Balanus amphitrite communis* as dominant species. Those from the recesses of the bay are simpler in their composition with *Hydroides norvegica* and *Watersipora cucullata* as the dominant species, and retarded in their stage.

3) Gradual transition in the constitution of the communities from the central part of the Bay to its recesses is observable. This is attributable to the gradual change of environmental conditions, such as, temperature, pollution and others, which are closely related to the renewal of water, but less so to the specific gravity of the water except for the community at Ugata.

4) Differences between the communities in the centre and the recesses of the bay closely resembe those between the communities in the lower and upper layers of the sea.

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A Notodelphyoid Copepod, *Pachypygus gibber* (THORELL), newly found in Japan

By

Shigeko OOISHI

Pachypygus gibber (THORELL) is a copepod belonging to the family Notodelphydae and is found parasitic in the pharyngeal cavity of certain solitary ascidians. This species which was first placed in the genus *Doropygus* by the original author was transferred later by G.O. SARS to another genus *Pachypygus* which he erected to accomodate the species. Diagnosis of this genus is lacking in the description of the setae with which the appendages are armed. The present report which is the first in recording the species from Japan lays much stress upon the point.

Doropygus gibber, THORELL, 1859a.

Pachypygus gibber, (THORELL), G.O. SARS, 1921.

Occurrence: 3 females in *Ascidia zara* OKA (new host), Tanabe Bay, Wakayama Prefecture, June 9, 1960; 2 females in *Styela plicata* (LESUEUR) (new host), off Oomishima, Ehime Prefecture, Inland Sea, Oct. 8, 1960; a female in *Ciona intestinalis* (LINNAEUS) and another in *Cnemidocarpa areolata* (HELLER) (new host), Matoya Bay, Mie Prefecture, Jan. 26, 1961.

Female: Color white when the marsupium is empty. Egg mass dark gray to black. Length, excluding urosome, 3 to 4mm. Body (Fig. 1, A) compressed, compact, squat and somewhat curved ventrally. Head of moderate sized. Metasome four-segmented, with segments larger in size from first to fourth in due order. Articulating regions between consecutive segments exposed or unexposed. Fourth segment accomodates a large and prominent brood sac which is angular at hinder extremity and excavated on ventral side. Urosome six-segmented, inclusive of fifth thoracic segment and a reduced perianal ring which bears caudal rami.

Antennule (Fig. 1, B) short and stout, nine-segmented. Proximal two segments elongate; first longer than second. Armature of this appendage consisting of short curved, nonserrated setae. Number of setae present on respective segments: 1st, 2; 2nd, 14; 3rd, 6; 4th, 5; 5th, 5; 6th, 4; 7th, 2; 8th, 3 and 9th, 8. Antenna (Fig. 1, C & D) distinctly three-segmented, sparingly setose. Basal segment without seta. Succeeding segment longest of all, bearing a seta on the outside. Terminal segment with a number of short slender setae and a trio of them on the inner surface, the central member of these longest. Terminal claw bears at its base four setae, of which three are situated laterally and one medially.

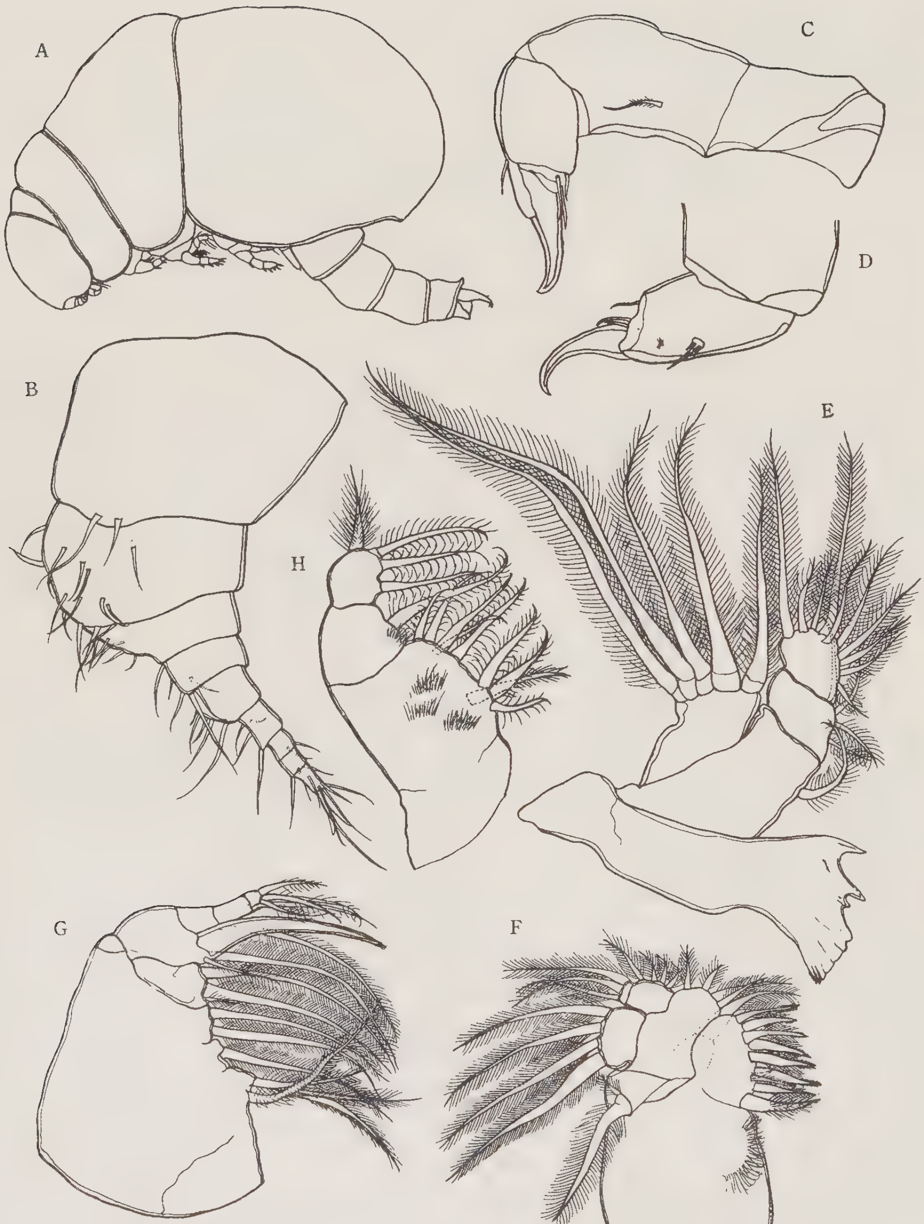

Fig. 1, *Pachypugus gibber* (Thorell), female. A, lateral view; B, antennule; C, antenna; D, same, inner side; E, mandible; F, maxillule; G, maxilla; H, maxilliped. A × 15; B, C, D × 170; E, F, G, H × 120.

Mouth parts well-developed. Mandible (Fig. 1, E) consists of a coxa, which is produced medially into a toothed masticatory plate, and basis carrying exopodite and endopodite. Basis bears a long stout plumose seta on the median side at a point

opposite to the insertion of exopodite. Exopodite monomerous, but retaining the trace of suppressed segmentation, and with five long plumose setae on lateral margin. Proximal two of these one and one third times as long as the remaining three which are subequal to one another. Endopodite bimerous, markedly longer than exopodite. Its basal segment shorter, but wider, with four plumose setae which are arranged on the median margin circumscribing a semicircular row. Terminal segment bears ten plumose setae, which form marginal row extending from the medio-proximal angle of the segment to the latero-distal angle; the outermost and the fourth from the outer angle are longer, much stouter than others which are subequal.

Maxillule (Fig. 1, F) has well-developed protopodite, monomerous exopodite and bimerous endopodite. The masticatory endite bears a median row of ten, relatively short, stout, but apically tapering setae, proximal two of which are slender and short. Second endite provided with an outgrowth as large as the stoutest of the masticatory setae. Four terminal setae of basipodite placed on anatomically median side. Endopodite two-segmented, with seven setae; its basal segment with a median row of four short, slender setae and much shorter distal segment with a terminal trio of longer, stouter setae, which are subequal to one another. Epipodite has a long, stout, acuminating seta, which is accompanied by a very short, plumose setule.

Maxilla (Fig. 1, G) pentamerous; its terminal three segments slender than the rest and the fourth the longest of them. Basal segment issuing four endite. Proximal endite with four of setae, second with a single one, third with two and fourth with two equal setae associated with a reduced accessory setule. Second segment of maxilla bears a heavily prehensile claw to whose base two setae are inserted. Third segment carries a long plumose seta at its medio-distal corner and fourth a single slender medio-distal seta. Terminal segment very short, bearing four subequal apical setae.

Maxilliped (Fig. 1, H) distinctly trimerous. Basal segment longest of all, ornamented with two groups of setae; proximal group composed of four setae, present on median margin, and the distal consisting of five. Second segment with a median seta, relatively long and slender. Distal segment shortest, round and having a median row of three long setae and a short distal one. Those setae present on mouth parts all plumose.

First pair of swimming legs (Fig. 2, A) of ordinary structure and with rami nearly equal in size. Protopodites of two sides connected together by a well-developed intercoxal plate. Median coxal seta moderately long, reaching distal end of second endopodite segment. Basipodite with a short lateral seta and with a stout, tapering medial spine, which extends a little beyond the distal border of second endopodite segment. Exopodite trimerous, armed with spines and setae, both six in number. Two proximal segments furnished each with a lateral spine and a medial seta. Distal segment bears three lateral and one apical spines and three median

and one apical setae. Endopodite also trimerous; two basal segments with a median seta respectively and terminal segment with three medial, two apical and one lateral setae.

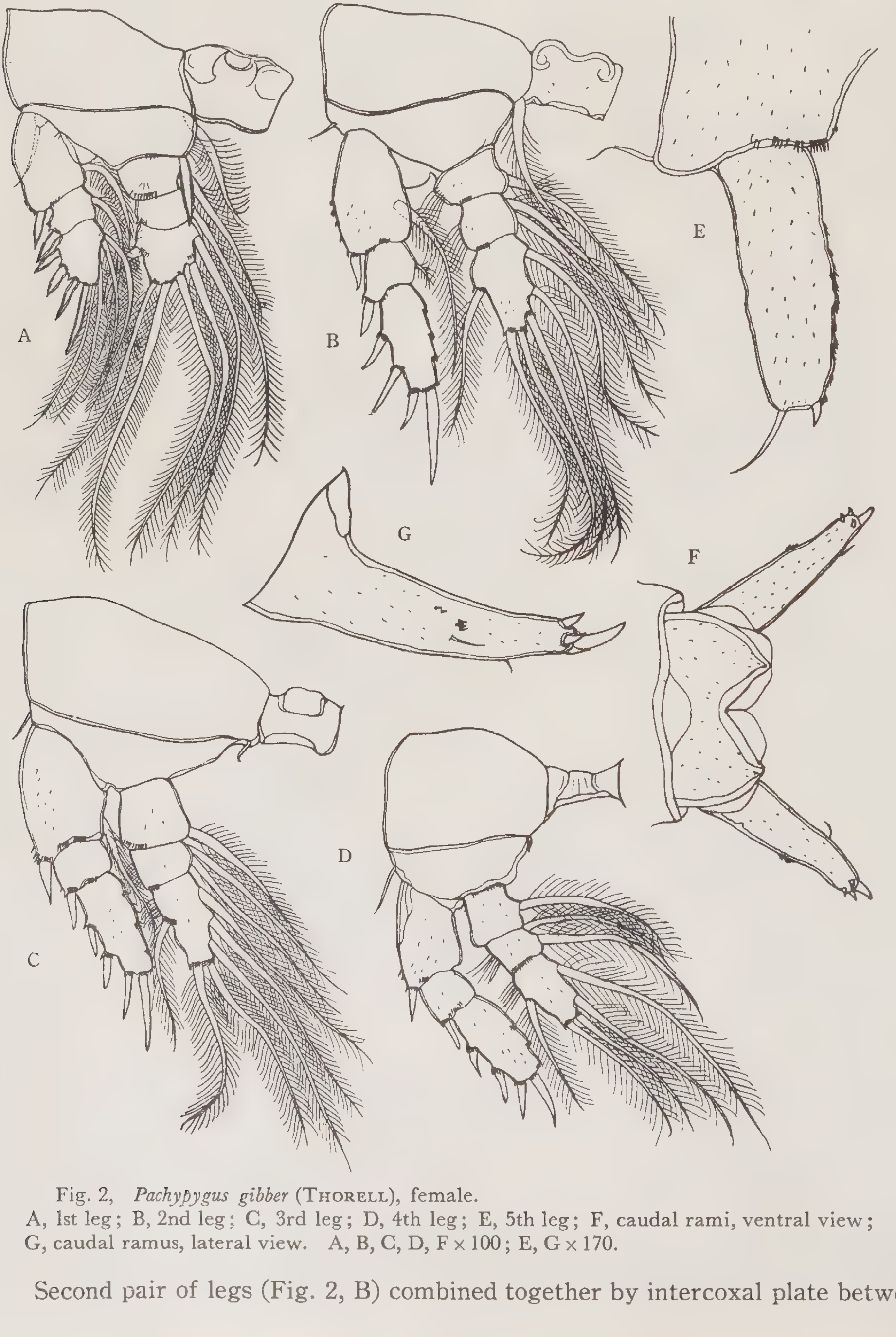

Fig. 2, *Pachypygus gibber* (Thorell), female.
A, 1st leg; B, 2nd leg; C, 3rd leg; D, 4th leg; E, 5th leg; F, caudal rami, ventral view; G, caudal ramus, lateral view. A, B, C, D, F × 100; E, G × 170.

Second pair of legs (Fig. 2, B) combined together by intercoxal plate between

the members of two sides. Coxopodite has a moderately long median seta and basipodite a fine reduced lateral seta. Exopodite longer than endopodite, both trimerous. The former flattened and heavily sclerotized. First segment of exopodite bears a short thick spine and a long plumose seta, the second a similar lateral spine and a short plumose seta which is absent from some specimens, and the third three stout lateral and one apical spines; ornamentation on the inner border of last segment or on last two segments in some specimens is represented by marginal row of fine spinules, or by a single pyramidal composite spine formed by the agglutination of a number of spinules. Endopodite has one median seta on first segment, two median setae on the second, and three median, two apical and one lateral setae on the third.

Third pair of legs (Fig. 2, C) with intercoxal plate and a short, median, non-hairy, coxal setule. Second segment of exopodite bears no seta. Otherwise, as in the preceding pair.

Fourth pair of legs (Fig. 2, D) relatively small in size as compared with the preceding three pairs and with reduced intercoxal plate. The trimerous exopodite entirely lacks setae. Otherwise, this pair of legs conforms to the third pair in structure.

Fifth pair of legs (Fig. 2, E) bimerous, especially sclerotized. Basal segment bears a short, slender seta on the outside at distal angle. Distal segment has a lateral seta and tiny spine turned outward and six to nine projections surmounted with fine spinules along the inner border.

Caudal ramus (Fig. 2, F & G) slightly curved downward like a claw and gradually attenuating toward the tip where it carries a stout spine accompanied by three shorter spines. It is armed, in addition, on its side two-thirds distally from its base with a short seta, with which several feebler denticles are associated, and with another similar seta one fifth proximad from the tip.

Male: Unrepresented in the present collections.

Remarks: The species is recognized before everything by its large-sized body which is invested with sclerotized integument. According to Sars' description on the specimens from Norway, the antennule is said to be composed of seven segments. Presence of nine segments in the present specimens appears to belong to a local variation. Sars gives a smaller number of setae on the antennule, antenna and mouth parts. This may be based, with all probability, on the fact that the setae are too fragile to be preserved in a perfect condition. In the third to fourth pairs of legs the seta on coxopodite is reduced to a setule. This may represents one of the characteristics by which the species can be discriminated from others. Another characteristic lies in that the greater part of the inner setae of the second to fourth exopodite is replaced by spinules.

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A new Notodelphyoid Copepod, *Pachypygus curvatus* n. sp., found in Japan

By

Shigeko Ooishi

The genus *Pachypygus* has hitherto been known from only two species, *P. gibber* and *P. macer*. Both of these live in the pharyngeal cavity of several kinds of solitary ascidians. Another species belonging to that genus was obtained by the author in the pharyngeal cavity of *Pyura michaelseni* (Oka), which is at present the sole host for the species.

Occurrence: 9 females, Gokasho Bay, Mie Prefecture, June 14, 1957; 30 females, off Oomishima, Ehime Prefecture, Inland Sea, Oct. 5, 1956; 3 females, Sugashima, Mie Prefecture, March 18, 1961.

Female: Color dirty yellowish in formalin. Length from the top of prosome to the end of brood sac 5mm. Body (Fig. 1, A) compressed, robust, compact and convex above. Prosome comparatively large, rounded anteriorly. Metasome four-segmented; first, second and third thoracic segments of moderate size, and fourth accomodated with a large brood sac which is not much inflated dorsally. Urosome (Fig. 2, H) composed of six well-defined segments inclusive of the fifth thoracic somite and anal ring. Integument heavily sclerotized and covered by spinules or tubercles (Fig. 1, B & Fig. 2, F, I, K). Rostrum (Fig. 1, B) large and long, elongate triangular with sides twice as long as the base.

Antennule (Fig. 1, C) nine-segmented, proximal two segments elongate and expanded, and the distal seven short and slender. Setal formulla as follows: 1st, 3; 2nd, 16; 3rd, 4; 4th, 9; 5th, 9; 6th, 3; 7th, 2; 8th, 2; 9th, 8. Two setae of first segment very long, surpassing a half of the total length of antennule. Ciliation on the antennular setae lacking.

Antenna (Fig. 1, D, E) strongly chitinized and distinctly three-segmented. The proportion of three segments from the basal to the apical is 10: 7: 7. First segment with two tiny setae at inner distal corner. Second with a similar seta at distal one third of outer border. Third has a mammiform papilla surmounted by four weak setae on inner surface at distal one third of its length and ends in a slender curved claw which is accompanied by four short basal setae.

Mandible (Fig. 1, F) consisting of bimerous protopodite, bimerous endopodite and unimerous exopodite. Medial border of masticatory lamella (Fig. G) divided into five teeth and truncate plate resulted from the fusion of minor denticles and

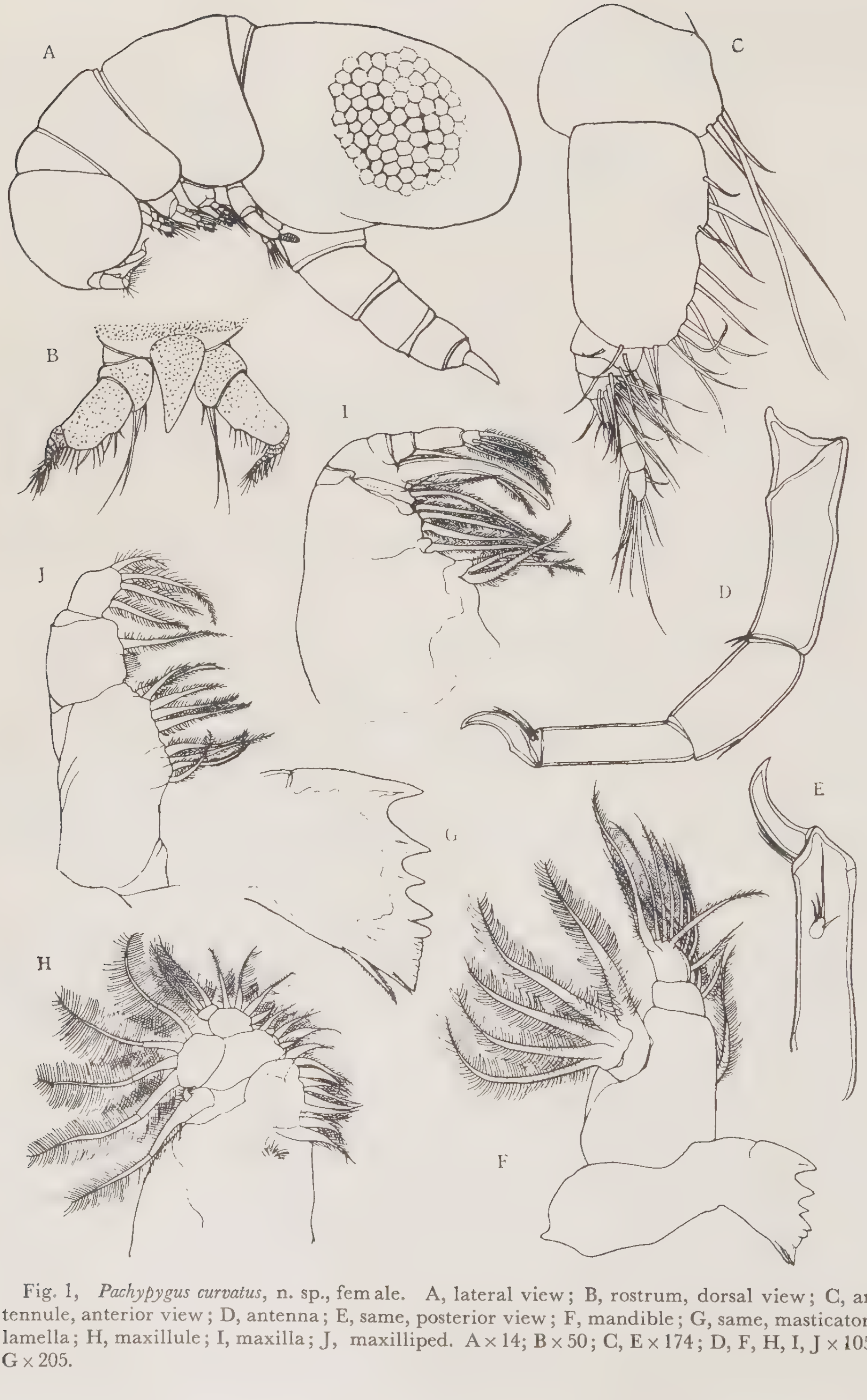

Fig. 1, *Pachypygus curvatus*, n. sp., female. A, lateral view; B, rostrum, dorsal view; C, antennule, anterior view; D, antenna; E, same, posterior view; F, mandible; G, same, masticatory lamella; H, maxillule; I, maxilla; J, maxilliped. A × 14; B × 50; C, E × 174; D, F, H, I, J × 105; G × 205.

bearing somewhat more proximally two setules. Basipodite carries a long plumose seta on inner margin. Basal segment of endopodite provided at medio-distal corner with four plumose setae of graded length; terminal segment with ten plumose setae circumscribing median and terminal margins. Exopodite segment suppressed and furnished with five plumose subequal setae.

Maxillule (Fig. 1, H) composed of bimerous protopodite, bimerous endopodite and monomerous exopodite. Outer distal angle of coxopodite has an epipodite represented by long stout plumose seta associated with a short basal setule. Basal endite large, rimmed with ten plumose setae of varying size along median margin. Second endite is a small projection terminating in a setiform elongation. Basipodite furnished with four inner plumose setae, of which the proximalmost is shortest. Endopodite with a series of four slender plumose setae on basal segment on median border and with three subequal plumose setae on the much shorter apical segment. Exopodite rectangular, bearing four long marginal plumose setae.

Maxilla (Fig. 1, I) five segmented, broad at the base, slender toward the tip and directed medially. Basal segment occupying more than half the entire mass and with four setiferous prominences representing endites. First endite with four plumose setae, second with a single one, third with two and fourth with two and a tiny setule. Second segment produced medially into a heavy claw to whose base two slender plumose setae are inserted. Third and fourth segments bear each a long plumose seta at distal median corner. Terminal segment small, carrying four slender subequal apical plumose setae.

Maxilliped (Fig. 1, J) consists of three setiferous segments. Basal segment armed on the median margin with nine plumose setae; these in two groups of four proximal and five distal. Second segment ornamented by a long slender plumose seta at the middle of median margin. Terminal segment shortest and supplied with four plumose setae on distal and median margins.

First pair of legs (Fig. 2, A) as usual in structure, consisting of two-segmented protopodite and three-segmented rami. Protopodites of both sides connected with each other by a more or less well-developed intercoxal plate and two rami almost equal in size. Long plumose seta present at medio-distal corner of coxopodite reaches the end of third endopodite segment. Basipodite carries a short slender lateral seta and a stout median spine which reaches distal third of first endopodite segment. Two basal segments of endopodite with a median plumose seta and the terminal with three median, two apical and one lateral plumose setae. First to third segments rimmed on lateral side with delicate hairs. Two proximal segments of exopodite with a median plumose seta and a lateral spine respectively. Terminal segment ornamented with four inner plumose setae and the same number of outer spines.

Second pair of legs (Fig. 2, B) with bimerous protopodite and trimerous rami. Intercoxal plate reduced. Coxopodite ornamented with a long plumose seta at medio-distal corner. Basidodite with a short slender lateral seta. Both rami highly chiti-

Fig. 2, *Pachypygus curvatus* n. sp., female. A, lst leg; B, 2nd leg; C, 3rd leg; D, same, 3rd segment of exopodite; E, 4th leg; F, same, 2nd & 3rd segments of exopodite, outer surface; G, same, inner surface; H, urosome, ventral view; I, 5th leg, ventral view; J, same, dorsal view; K, caudal ramus, ventral view; L, sama, terminal end. A, B, C, E × 105; D, F, G × 174; H × 14; I, J × 121; K × 88; L × 244

nized. Basal segment of endopodite with one plumose seta at the distal third of median margin. Second segment carrying two long plumose setae on the same margin. Terminal segment with three median, two apical and one lateral plumose setae. First to third segments rimmed on lateral side with delicate hairs. Exopodite modified, and bent slightly inwards at articulation between first two segments. Proportional lengths of these segments from basal to distal is as follows: 5: 1: 2. Ornamentation of first segment consists of a outer distal spine and a inner plumose seta present at the middle of the segment. Second segment with a lateral spine and a simple median seta. Terminal segment with four outer spines and five inner setae. Setae of second to third segments (Fig. 2,D) weak, short and inconspicuously ciliated.

Third pair of legs (Fig. 2, C, D) show the modification same as those of second pair.

Fourth pair of legs (Fig. 2, E, F, G) with bimerous protopodite, and trimerous rami of distinctly unequal structure. Intercoxal plate further reduced than in preceding legs. Coxopodite with short plumose median seta, exceeding distal end of basipodite. Basipodite with a short slender lateral seta. Endopodite relatively shorter than the corresponding ramus of preceding legs and half as long as exopodite. First segment armed with a short seta, second with two long setae, and third with two median, two apical and one lateral setae. All the setae of endopodite segment plumose. First to third segments furnished by delicate hairs on lateral side. Three segments of exopodite enlarged, and twisted around its axis so as to direct the side margin towards the outer surface. Basal segment longest, equaling to combined length of distal two segments which are subequal. Anatomically lateral margin furnished with several trnsverse rows of denticles and a spine at distal end. Second segment carrying a short fine lateral spine and a short slender median seta. Third segment linguiform, furnished with a number of transverse rows of tubercles or denticles on inner surface and with two stumpy lateral spines, two longer terminal spines and five median setae. All the setae on exopodite weak, short and practically lacking ciliation.

Fifth pair of legs (Fig. 2, H, I, J) bimerous. Basal segment indistinctly articulated to urosome, furnished by a short seta at outer distal angle and transversed by rows of spinules on the median side margin. Second segment three fourths as long as basal segment, ending in a longer outer seta and a shorter inner spine. Median and dorsal side of the segment has four to five rows of marginal spinules.

Caudal rami (Fig. 2, K, L) short, but stout, about three times as long as its width at the base and tapering distally. They terminate in a short stout spine accompanied by three much shorter spines and carry a short slender seta at the middle of the median and dorsal sides.

Male: Unrepresented in the collections.

Remarks: The present form is large in size and invested by a strongly chitinized integument. It is in agreement with *P. gibber* and *P. macer* in most of the

anatomical details: In the nine-segmented antennule having the two basal segments dilated, in the three-segmented antenna much reduced in setation, in the mandible posessing two-segmented endopodite, in the exopodite of maxillule having four setae, in the second segment of maxilla armed with unguiform process, in the maxilliped having all the three segments setiferous, in the second to fourth swimming legs being more or less reduced in the setation of the exopodites, and in the caudal ramus carrying four stout terminal spines. The species, however, can be distinguished from other two species of *Pachypygus* by the modified exopodites of the second to fourth legs, especially of fourth.

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Eine neue Art der Gattung *Argathona* (Crustacea, Isopoda: Flabellifera, Corallanidae) aus Japan

By

Sueo M. SHIINO

Zwei Exemplaren von einer Isopodenart, die in der Bucht von Sagami gesammelt worden waren, wurden mir vorletztes Jahr aus dem Biologischen Laboratorium Ihrer Majestät des Kaisers zusammen mit einigen anderen Crustaceen zur Identifikation zugesandt. Die nähere Untersuchung dieser Isopoden zeigte, daß sie einer neuen Art der Gattung *Argathona* angehören, die unten ins Detail beschrieben wird.

Genus *Argathona* STEBBING
Argathona japonica sp. nov.

Fundort: Zwei Weibchen, in der Bucht von Sagami. Nr. 1607: an Okinoyama, 85–95m., 24. Juli 1959. Nr. 1640: an demselben Orte, 80m., 25. Juli 1959. Das letztere Exemplar wird zum Holotypus gewählt.

Holotypus (Abb. 1 u. 2): Länge 18.8 mm, Breite im 5. Pereiomere 7.5 mm. Farbe im Alkohol gelblich, gesamte Oberfläche aber dicht mit kleinen Pigmentflecken. Körper spindelförmig, dorsal wohl convex.

Cephalon so lang wie 1. Pereiomer, dreimal so breit wie eigene Länge, dreieckig und mit weit gebogenem Vorderrande, der in der Mitte eine sehr leichte Spitze bildet. Augen voneinander abgetrennt, seitlich, bis zur Ventralfläche erreichend und wurstzipfelartig in Dorsalansicht. Epistom schmal, länglich fünfeckig und zwischen den Basen der Antennen geraten.

Pereion breitest am 4. oder 5. Segmente und von da verschmälert sich allmählich nach vorn sowie hinten. Erste zwei Segmente fast gleich lang und kürzer als die folgenden drei, die ihrerseits wieder untereinander beinahe gleiche Länge aufweisen; letzte zwei etwas kürzer als die vorhergehenden. Reihenfolge der exakten Pereiomerenlänge in der Mittellinie sind: 5., 4., 3., 6., 7., 2. und 1. Mit Ausnahme vom 1., haben alle Pereiomere gut abgesonderte Epimere, die sich in den 2. und 3. an der hinteren Kante abgerunden, in den anderen aber hintenwärts spitz zulaufen und sich von vorn nach hinten in zunehmendem Maße verlängern. Diese weisen auf der Oberfläche eine schief verlaufende Erhöhungslinie auf. Seitenteile der Segmenten sind mit den Epimeren einschließlich mehr oder weniger behaart; die Behaarung besetzt rückwärts immer zunehmend breitere Region. Bauchseite des Pereions ist wohl angeschwollen, doch ohne Oostegitenpaare.

Pleon ein wenig kürzer als ein Drittel der gesamten Länge. Das 1. Pleomer

versteckt sich unter dem letzten Pereiomere; folgende vier sehr kurz, untereinander gleich lang, von vorn nach hinten etwas verbreitert mit Ausnahme vom 5., das sch-

Abb. 1. *Argathona japonica* sp. nov., Weibchen.
A, Dorsalansicht; B; Seitenteile des Pereions und Pleons; C, Vorderende des Cephalons, Ventralansicht; D, Mandibel; E, Kaurande der Mandibel; F, 1te Maxilla; G, Endklauen des Exopoditen derselben; H, 2te Maxilla; I, Maxilliped; J, Randstacheln der Maxillipedenpalpen. A × 5.6, B × 10, C × 19, D–F, H, I × 42, G, J × 170.

mäler als alle andere ist. Alle Pleomere an den Hinterrändern entlang behaart. Pleotelson dreieckig, so breit wie 5. Pleomer, etwas länger als die Hälfte der eigenen Breite, mit leicht schlängelnden Seitenrändern und abgerundetem Kaudalende. Gesamte Dorsalfläche mit kürzeren Haaren bedeckt, freier Rand ringsum mit längeren Haaren besetzt und Kaudalende überdies mit einer Reihe von Dornen bewehrt. Wegen der Beschädigung des Kaudalendes auf der linken Seite, sind nur sieben Dornen wahrnehmbar.

Antennula erreicht die Hinterecke des Cephalons und besteht aus zweigliedrigem Stiele, dessen proximales Glied etwas länger als das distale ist, und 19-gliedriger Geißel, die an jedem Gliede auf der Hinterseite dicht mit längeren Haaren und auf der Vorderseite spärlich mit kürzeren besetzt wird. Antenne erstreckt sich bis zum Hinterrande des 7. Pereiomeres. Ihr Stiel geht an dem 1. Pereiomere ein wenig vorüber und besteht aus fünf Gliedern, unter denen die distalen zwei miteinander beinahe gleich lang und viel länger als die proximalen drei sind, welche untereinander beinahe gleich lang sind; 1. Glied ist dreieckig, 2. mehr kurz als breit und die beiden entbehren die Behaarung, während die anderen am Ende spärlich behaart sind. Geißel 36-gliedrig und sehr spärlich behaart. Clypeus V-artig; Labrum kurz, aber breit und mit gebogenem Rande. Mandibel besitzt den kaum gezähnelten Inzisorfortsatz und die gutentwickelte, dreigliedrige Geißel, deren distale zwei Glieder äußerlich dicht behaart sind. Exopodit der Maxillula endet in einen großen, zugespitzten Zahn, der zwei kleinere Zähnchen von verschiedener Länge sowie andere zwei weiter kleinere, rudimentäre begleitet; Endopodit am Ende abgeflacht. Maxille ist eine einfache verlängerte Lamelle, deren vorderer Rand nahe an der Innenkante seicht eingekerbt und weiter innen spärlich behaart ist. Maxilliped schmal; zwei basale Glieder gegeneinander senkrecht stehend. Palpus viergliedrig; 2. Glied ist beweglich am 1. eingelenkt, so lang wie das 3. und 4. zusammen und weißt in der Mitte eine seichte querlaufende Linie auf, die Grenze zwischen den verschmolzenen Gliedern andeutet. Mit Ausnahme vom 1. werden alle Glieder an beiden Rändern durch längere und kürzere Haare gesäumt; die längere Haare sind mit sekundären, kammartig angeordneten, winzigen Stacheln an ihrer Achse versehen.

Erste drei Pereiopoden sind nach vorn gebogen, während die folgende vier nach hinten gerichtet. Jene sind untereinander gleich gebaut, fast gleich groß, wenn auch nur der 1. ein wenig kleiner ist. Basipodit Jener Füßen ist lang gestreckt, terminal mit einigen Haaren versehen und auf beiden Rändern sehr spärlich behaart. Ischiopodit viel kürzer und vorn dorsal mit zwei Dornen bewehrt. Mero- und Carpopodit kurz und miteinander gedrängt; der erstere trägt vorn dorsal drei Dornen, am ventralen Rande entlang innere Reihe von etwas kürzeren vier und äußere Reihe von viel winzigen stumpfen fünf; der letztere besitzt nicht mehr als ein kleines ventrales Dörnchen. Propodit auf dem ventralen Rande mit zwei Dörnchen und am distalen Ende mit einem etwas kräftigeren Dorn versehen. Dactylopodit stark gekrümmt. Hie und da spärlich behaart jedes Glied. Letzte vier Pereiopoden länger als die vorhergehenden, ihrerseits untereinander gleich gebaut und mit wohl verlän-

gerten Gliedern. Unter ihnen ist der 4. Pereiopod am kürzesten und der 6. am längsten. Glieder vom Ischiopodit bis zum Propodit sind auf dem Hinterrande mit doppelter Reihe von wohlentwickelten Dornen bewaffnet und sind auf dem distalen Rande entlang so innerlich als auch äußerlich mit einer Anzahl von kräftigen Dornen umgeben, die entweder doppelt gezähnelt, oder überdies mit paarigen sekundären Zweigen versehen sind. Dactylopodit weniger gekrümmt, als in den vorangehenden Füßen.

Alle Pleopoden von demselben Aufbaue und mit verlängert ovalen beiden Ästen, die dicht mit kurzen, befiederten Borsten gesäumt werden. Am Exopodit erreicht die Borstenreihe von der Basis ihres Außenrandes bis an der Mitte des Innenrandes, am Exopodit aber ist sie nur auf den terminalen Rande beschränkt. Protopodit ist an der Innenseite mit einigen ebensolchen Borsten versehen. Von den vorhergehenden etwas verschiedend, ist der letzte Pleopod sehr spärlich beborstet auf dem Endopodit, der nur mit einer Borste an der Spitze bewaffnet ist.

Uropod erstreckt sich kaum über das Hinterrande des Pleotelsons. Sein Protopodit verlängert sich auf der Innenseite hinten nach zu einem spitz zulaufenden Lobus, das innen mit einer Reihe von langen Haaren versehen ist. Exopodit ist schmal, spindelförmig, aber endet stumpf und besitzt an beiden Rändern die in einer Linie dicht aufgestellten Haaren, in die sich andere Linie von kürzeren Dornen einschiebt. Anzahl der Dornen ist im rechten Uropoden an der Innenseite 6, an der Außenseite 8 und im linken Uropoden an der ersteren 7, an der letzteren 10. Die Oberfläche des Exopoditen ist auch behaart in der Partie, die sich unter den Endopoditen nicht versteckt, wenn die beiden verschlossen werden. Der Endopodit ist breiter als der Exopodit, verlängerte Dreiecke in Form und wenig gebeugt am Außenrande, der in eine stumpfe Spitze endet, und den beinahe gerade, vielmehr leicht eingebuchtete Kaudalrande, der sich durch die abgerundete Innenecke an den geraden Innenrande anschließt; fast ganze Oberfläche ist behaart und Außen- und Kaudalrand sind mit reihenartig angeordneten Haaren und Dornen geschmückt, die beim linken Endopoditen auf dem Innenrande in 8 und auf dem Außenrande in 6, dagegen beim rechten Endopoditen auf beiden Rändern in 9 vorhanden sind.

Paratypus: 6.9 mm lang und 4.7 mm breit am 5. Pereiomere. Pleotelson mit einem Paare undeutlicher Geschwülste an der vorderen Partie. Sein Kaudalende unschadhaft, abgerundet und mit 8 marginalen Dornen bewaffnet. Exopodit der 1. Maxilla besitzt 1 große, 2 kleinere und nur 1 kleinste Klauen. Meropodit der ersten 3 Pereiopoden endet in 1 Dorn, ventraler Rand des Carpopoditen hat 4 stumpfe Dornen auf der Innenseite und 2 zugespitzte Dornen auf der Außenseite. Exopodit des Uropoden von der beiden Seiten mit 10 Dornen am Außenrande, 6 am Innenrande und Endopodit mit 6 am Außenrande und 9 am Terminalrande. Übrigens wie beim Holotypus.

Bemerkung: In der generalen Gestalt hat die vorliegende Art eine große Ähnlichkeit mit der wohlbekannten Art *Argathona macronema* Bleeker. Sie unterscheidet sich aber von dieser Art durch die Zähnenzahl der 1. Maxillen, die kürzere Haaren-

kleidung des Körpers und die Gestaltung des Uropoden, indem sie den Endopoditen am Kaudalrande nicht abgerundet, sondern vielmehr eingebuchtet hat.

Abb. 2. *Argathona japonica* sp. nov., Weibchen.
A, 1. Pereiopod, Außenseite; B, derselbe, Innenseite; C, 6. Pereiopod, Außenseite; D, derselbe, Innenseite; E, terminale Stacheln des Carpopoditen desselben Fußes; F, 1. Pleopod; G, Pleotelson und Uropod, rechter Hälfte. A, G × 19, B-D, F × 27, E × 82.

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Studies on the Swim-bladder of Goldfish (*Carassius auratus* L.) in Special Reference to the Relation between the Bladder and the Caudal Neurosecretory System

N. Y. Kawamoto

Preface

In 1955 Enami found the existence of the caudal neurosecretory system at the extremity of the spinal cord in various kinds of fish.

According to his report, the system secretes a hormone (1958), and plays a role not only in the mechanism of buoyancy of the fish (1958), but also in osmoregulation (1956).

The present writer has refered to the result of removing the caudal neurosecretory system of goldfish (1960), and presented further studies on the relation between the swim-bladder and the caudal neurosecretory system of goldfish.

Method of Experiment

The study has been carried out in the three following stages: (1) observations were made on the change in the swim-bladder of the tailless goldfish according to the method described by Enami (1958), (2) after a lead weight has been fastened under the anterior or posterior extremity of the normal body of a goldfish, observations were made concerning changes in the bladder form, as reported by Terao *et al* (1956), (3) under the extremity of the tailless fish, i.e. the mandible or posterior end of the fish, a weight was also fixed and observations were made as to whether or not change in the bladder occurred.

As preparation for these experiments, the fish were anesthetized by a urethan solution and all fins except the dorsal one were removed. Then, the tail was cut off at the level of the hind base of the anal fin as had been shown by Enami (1958).

Thrombogen was injected into the body of the fish before the operation, and after that, heated needle was applied to the cut end of the caudal aorta to stop excessive bleeding during the operation.

In order to compare change in the swim-bladder, the writer took X-ray photographs before and after the operation, and examined the areas of the bladders on those figures by using a planimeter and comparing their variations.

Although it is conceded that a plane surface measure is not entirely adequate

under such circumstances because of the shape of the bladder, the planimeter may be admitted as conventional means.

Results of Experiment

As material, goldfish from 5 cm to 12 cm in body length were used. Tail and fins were removed by the method described above.

Enami (1958) stated that the white variety of the common, simple tailed goldfish withstood the operation fairly well, as less than 5% mortality was observed during the 7 days following the first operation. However, it is generally recognized that the white variety of fish is too weak for handling. Therefore the writer used common goldfish instead of white variety.

When the tails of the fish were removed, the axial balance of the body was upset, and the anterio-posterior equilibrium was lost, with the consequence that the fish settled motionless on the bottom of the aquarium.

On the 8th post-operative day, Enami (1958) had selected the fish from those lying motionless on the bottom of the aquarium, and tested them for buoyancy. But, throughout the present writer's entire experiments, he could find scarsely any one which was submerged continuously.

After the operation, almost of the tailless fish submerged quietly on the bottom of the aquarium, but after then, little by little, began to swim freely as if they had recovered their health. In such a way, the fish that had been operated lived for a long time.

From this, the writer concluded that the submerging of the tailless fish resulted from the strong stimulation of the tail cutting operation.

As the fish always acted in the manner described above, the writer considered it useless to carry out the buoyancy test by injecting hormone or zinc sulphate solution as Enami had done in his experiment within the 8th post-operative day.

Almost all tailless fish swim with their heads down, as is shown in Figures 1 and 2 in Enami's paper (1958, p. 51). The writer could not determine whether this loss of balance was due to the removal of the neurosecretory system, or to the removal of the tail. To clarify this question, the writer made a hole in the posterior extremity of the spinal cord by inserting a heated needle to destroy the caudal neurosecretory system as shown in the figures (Plate I, Figs. 1, 2).

Even after such treatment, although they submerged on the bottom of the aquarium, their axial equilibrium was unchanged and the fish began to swim normally again. But, when the tail was cut off at the level of the hind base of the anal fin, the axial balance of almost of the fish was upset (Plate 1, Fig. 3). The writer concluded that the loss of the tail had upset the axial balance of the body of the fish, and caused it to swim with its head down.

Experiment 1.

The writer examined the change in size of the swim-bladders in tailless fish.

The results of experiments are shown in Tables 1–3 and Plate I, Fig. 3, Plate II, Figs. 4, 5, Plate III, Fig. 6. The sizes of the swim-bladders were compared with their areas shown on the X-ray photographs.

Table 1.
Change in sizes of the swim-bladder of tailless goldfish.
(compare with Plate II, Fig. 4, D_1-D_5)

No.	Date	Sizes of swim-bladder	
		Anterior lobe	Posterior lobe
D_1	II–16	0.018	0.013
D_3	II–19	0.017	0.013
D_5	II–28	0.017	0.008

From the tables and figures shown above, it is evident that the posterior lobes of the swim-bladder gradually became smaller and at last, (Table 2, Plate II, Fig. 5, H_8) completely disappeared.

These changes in the sizes of the lobes of the swim-bladders were evidently caused by the mechanism designed to regulate the axial balance of the tailless body, even when the caudal neurosecretory system was missing.

Table 2.
The same as above
(compare with Plate II, Fig. 5, H_4-H_8)

No.	Date	Sizes of swim-bladder	
		Anterior lobe	Posterior lobe
H_4	III–17	0.014	0.005
H_7	III–23	0.014	0.002
H_8	IV–14	0.013	Nothing (?)

Table 3.
The same as above
(compare with Plate III, Fig. 6, J_1-J_4)

No.	Date	Sizes of swim-bladder	
		Anterior lobe	Posterior lobe
J_1	II–28	0.017	0.011
J_2	III–16	0.017	0.008
J_4	IV–14	0.017	0.004

From the existence of gas bubble in the abdomen (Plate II, Fig. 4, D_5), it is supposed that the gas in the posterior lobe passes through the intestine, and out through the anus to help recover the boby equilibrium.

Experiment 2.

To study the power of the normal fish to control body equilibrium, weights were attached to the extreme ends of the fish, i.e. under the mandible or also the posterior end of the body, and changes in the sizes of the bladder were observed. The results are shown as follows:

Tables 4, 5, and Plate III, Fig. 7 and Plate IV, Fig. 8 show the change of swim-bladders of the normal fish to which the weights were fixed under their posterior end of the tail.

Table 4.
Change of size of the swim-bladder of normal fish to which a lead weight had been fixed under the posterior end of the tail (compare with Plate III, Fig. 7, A_2-A_7)

No.	Date	Sizes of swim-bladder	
		Anterior lobe	Posterior lobe
A_2	II-14	0.021	0.020
A_4	II-19	0.018	0.024
A_7	III- 6	0.012	0.022

Table 5.
The same as Table 4
(compare with Plate IV, Fig. 8, C_3-C_6)

No.	Date	Sizes of swim-bladder	
		Anterior lobe	Posterior lobe
C_3	II-20	0.016	0.015
C_4	II-28	0.014	0.016
C_6	III- 6	0.015	0.020

These two tables and figures show the tendency of more expanding the posterior lobes rather than decreasing the anterior one.

Tables 6, 7 and Plate IV, Fig. 9 and Plate V, Fig. 10 show the change of swim-bladders of the normal fish to which the weights were fixed under their mandibles.

Table 6.
Change of the swim-bladder of normal fish to which a lead weight had been fixed under the mandible (compare with Plate IV, Fig. 9, H_2-H_4)

No.	Date	Sizes of swim-bladder	
		Anterior lobe	Posterior lobe
H_2	II-20	0.013	0.009
H_3	II-28	0.015	0.008
H_4	III- 6	0.014	0.007

Table 7.
The same as Table 6
(compare with Plate V, Fig. 10, I_1-I_3)

No.	Date	Sizes of swim-bladder	
		Anterior lobe	Posterior lobe
I_1	II-20	0.016	0.016
I_2	II-28	0.018	0.013
I_3	III- 6	0.017	0.012

These results indicate that fish to which weights had been fixed under the mandibles underwent a contraction of the posterior lobes and a slight expansion of the anterior ones.

Experiment 3.

To determine whether the removal of the caudal neurosecretory system affected the change of the posterior lobe of a tailless fish, the following experiment was carried out. A weight was fixed under the posterior end of a tailless fish.

The table 8 and Plate V, Fig. 11 show that the posterior lobe expanded even in the absence of the caudal neurosecretory system.

From result of this experiment, the writer supposed that the removal of the neurosecretory system does not affect the change in the size of the bladder, and that the ability to recover axial balance is independent of this neurosecretory system.

To confirm these findings, a further experiment was undertaken. A week after

Table 8.
The influence on the swim-bladder of a weight fixed under the posterior end of the tailless fish (compare with Plate V, Fig. 11, A_1-A_3)

No.	Date	Sizes of swim-bladder	
		Anterior lobe	Posterior lobe
A_1	III–17	0. 022	0. 019
A_2	III–23	0. 024	0. 022
A_3	IV–14	0. 024	0. 026

the operation, the posterior lobe of the tailless fish appeared to be contracted. A weight was then fixed to the posterior end of the body. After 23 days, the posterior lobe was observed to have expanded again as shown in Table 9 and Plate VI, Fig. 12.

Table 9.
Contraction and expansion of the posterior lobe of the tailless fish by the axial unbalance (compare with Plate VI, Fig. 12, F_1-F_5)

No.	Date	Anterior lobe	Posterior lobe	Remarks
F_1	II–20	0. 012	0. 014	Normal fish.
F_2	II–28	0. 012	0. 009	After operation, a week elapsed and a weight was attached to its tail.
F_5	III–23	0. 013	0. 012	23 days after a weight had been fixed under the posterior end.

These results of experiments clearly indicated that the contraction or the expansion of the swim-bladder occurred equally with or without the caudal neurosecretory system.

Conclusion

Enami used only the tailless fish which had been operated on not more than eight days before the experiment for buoyancy. Hence, they were still lying head down on the bottom of the aquarium.

The present writer found that for eight days after such an operation, almost of the tailless goldfish acted in the same manner. However, the writer noticed that as more time elapsed, the tailless fish began gradually to swim freely once more about the aquarium without the existence of the caudal neurosecretory system. From this fact he assumed that the severe stimulation of the tail-cutting operation had caused the fish to lie inert for the 8th-day post-operative period.

Because of the above observation, the writer did not repeat ENAMI's buoyancy experiments by examining the effect of the hormone from the caudal neurosecretory system, or of a zinc sulphate solution on the tailless fish.

When the writer compared the results of all experiments described above, he concluded that the changes in size of the swim-bladder occurred whether the caudal neurosecretory system war present or not.

In other words, from the limited experiments performed thus far, the writer concludes that the existence of the caudal neurosecretory system does not directly affect the size of the bladder.

The writer also concludes that the mechanism for regulating the axial balance of a fish may be independent of the caudal neurosecretory system.

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Explanation of Plate I.

Fig. 1. A hole was made by the heated needle in the posterior extremity of the spinal cord to destroy the caudal neurosecretory system in each of three fish 7, 8 and 9.

Fig. 2. Fish thus operated showed no axial unbalance and submerging on the bottom in the begining.

Fig. 3. After the tails of these three fish which were cut off at the level of the hind base of the anal fin, the axial balance was upset. The fish swam with their heads down except in V.

Plate I

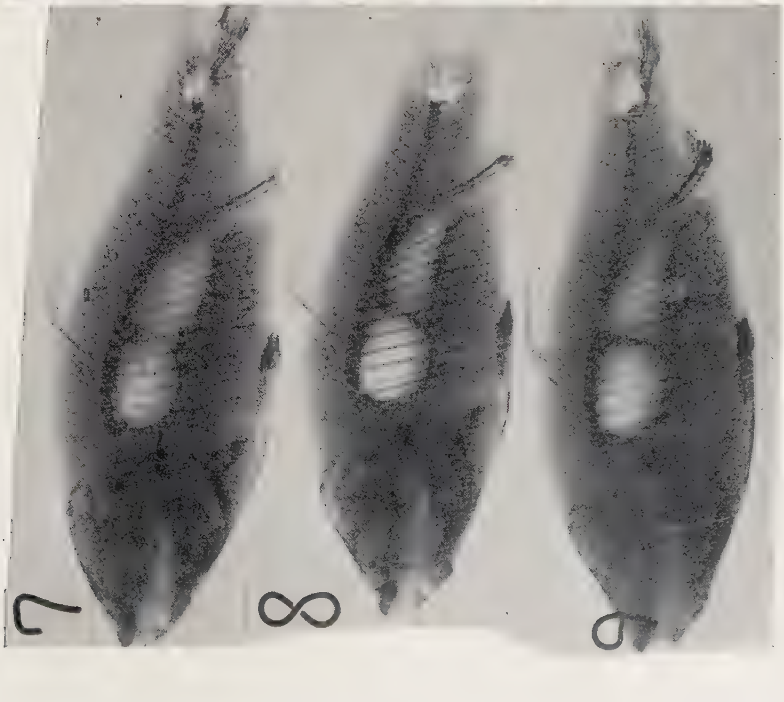


Fig. 1.

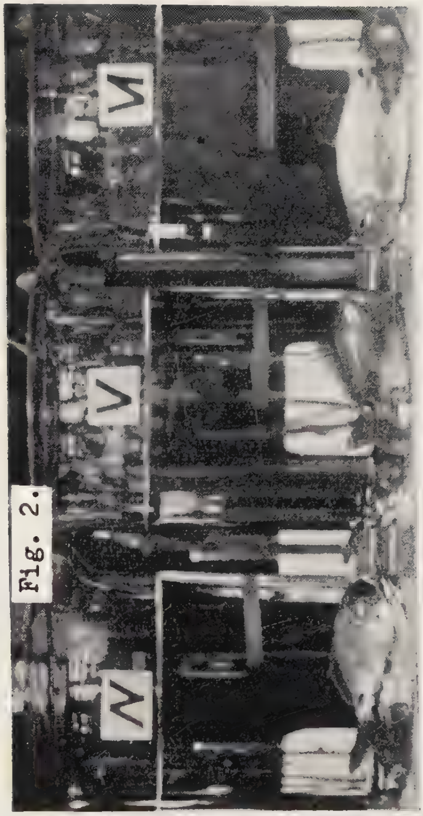


Fig. 2.

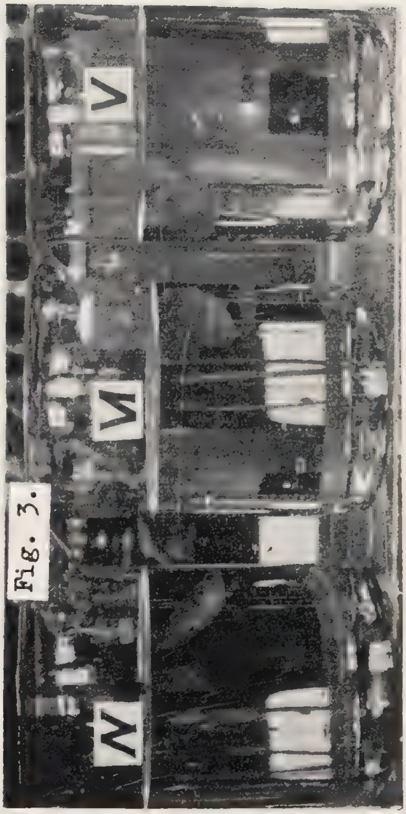


Fig. 3.

Explanation of Plate II.

Fig. 4. and Fig. 5. The posterior lobes of the bladder of the tailless fish began to become smaller and smaller and at last one of them disappeared as shown in Fig. 5.

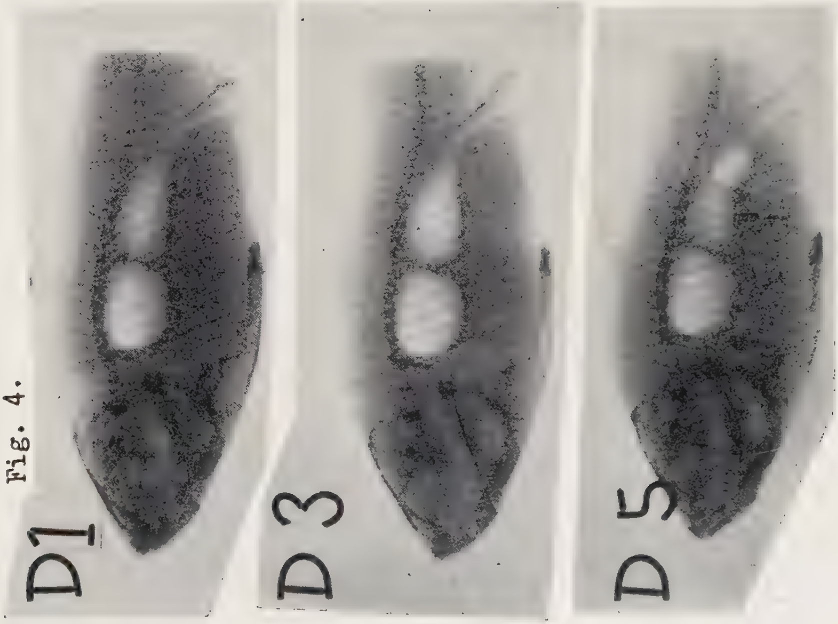


Fig. 4.

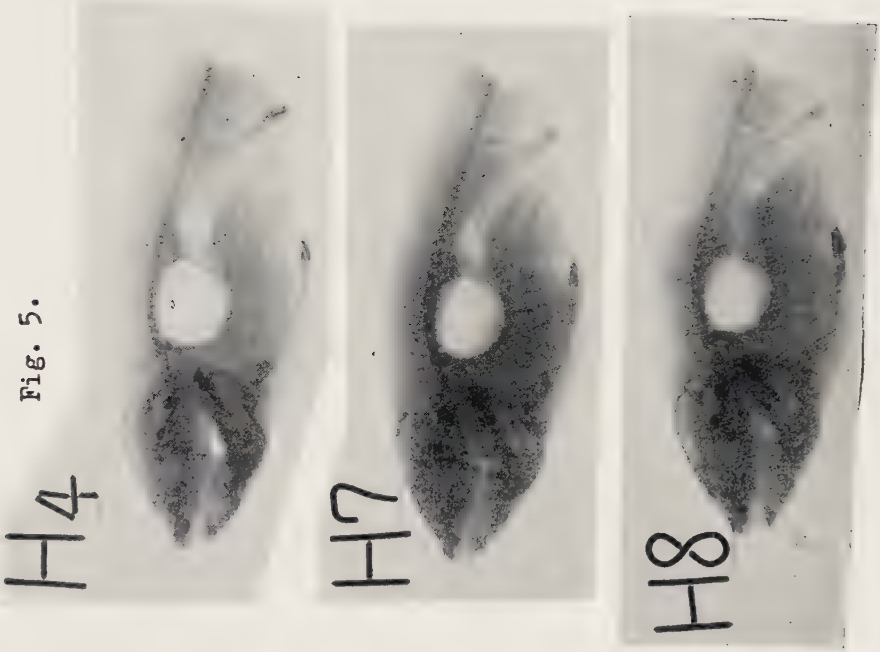


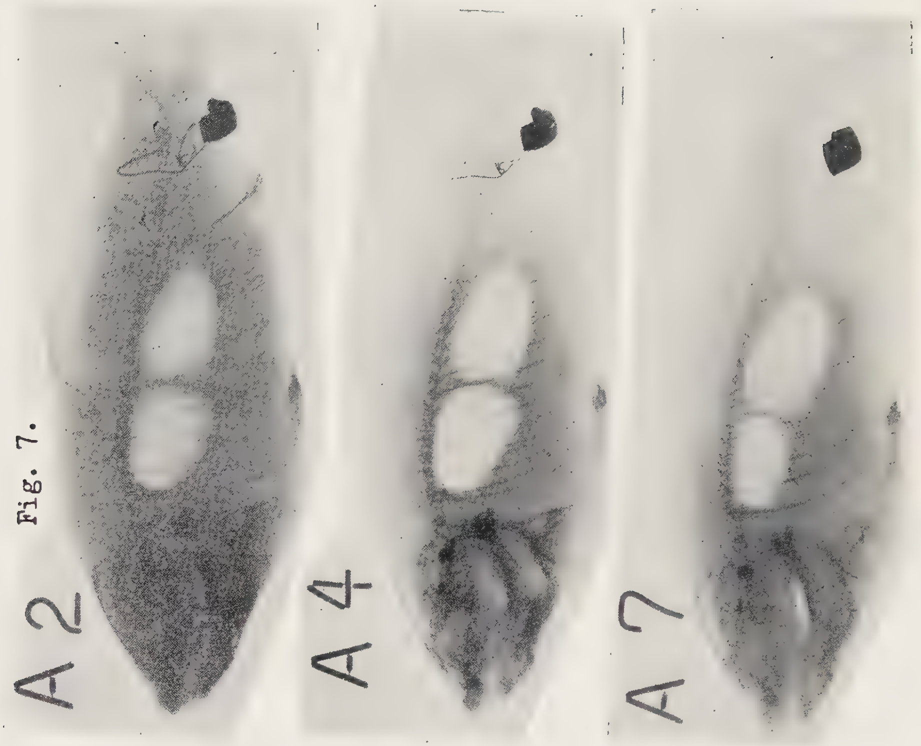
Fig. 5.

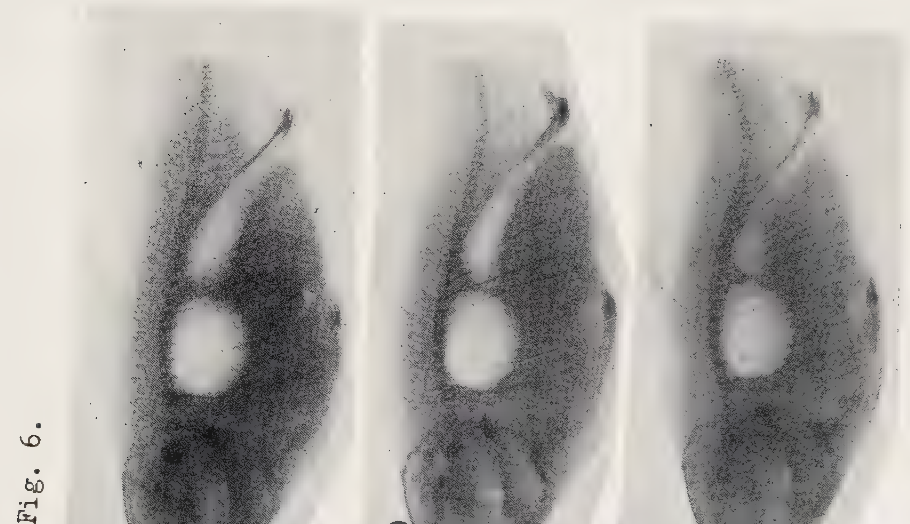
Explanation of Plate III.

Fig. 6. The same as Fig. 4, and Fig. 5.

Fig. 7. Showing expansion of the posterior lobe of normal fish to which lead weight had been attached under the posterior end (in A_7, a silk thread was used in place of the wire).

Plate III





Explanation of Plate IV.

Fig. 8. The same as Fig. 7.

Fig. 9. Showing the contraction of the posterior lobes of a normal fish to which a weight was attached under the mandible.

Plate IV

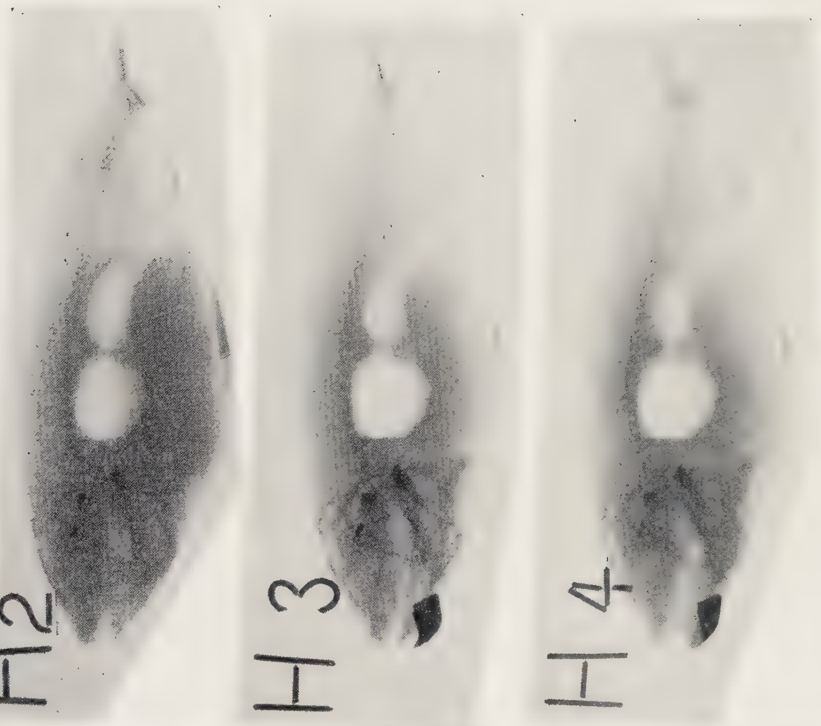


Fig. 9.

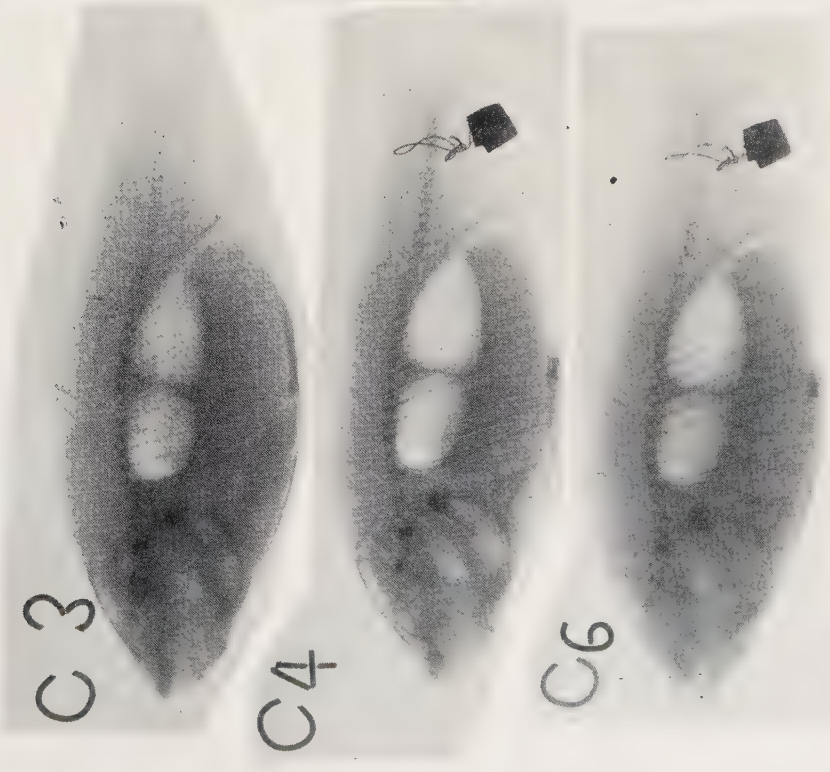


Fig. 8.

Explanation of Plate V.

Fig. 10. The same as Fig. 9.

Fig. 11. Showing expansion of the posterior lobes of tailless fish to which a weight had deen attached under the posterior end of the body.

Plate V

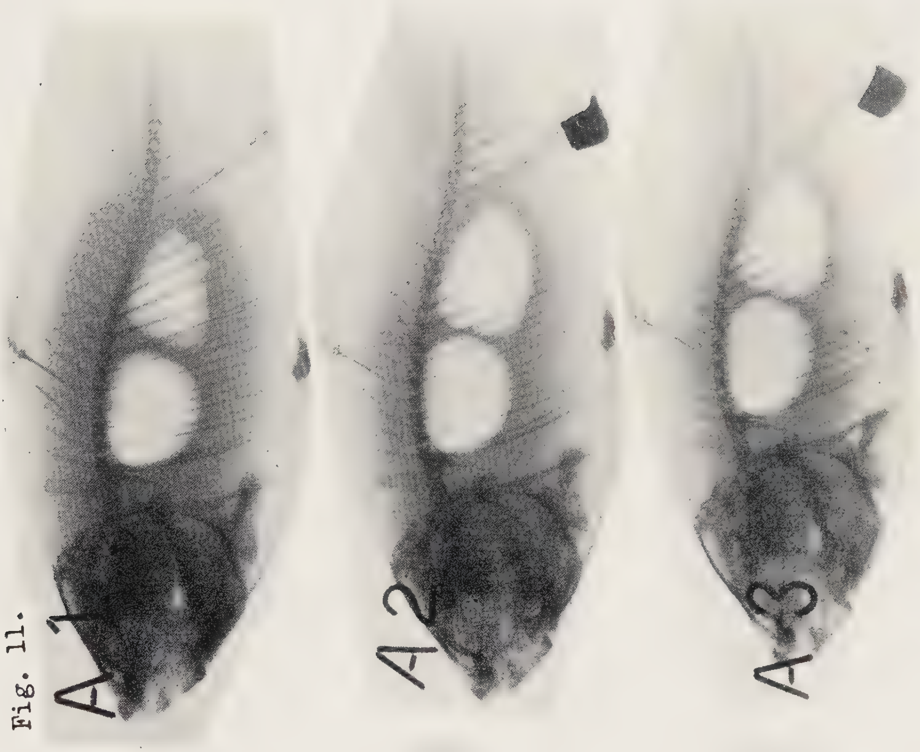


Fig. 11.

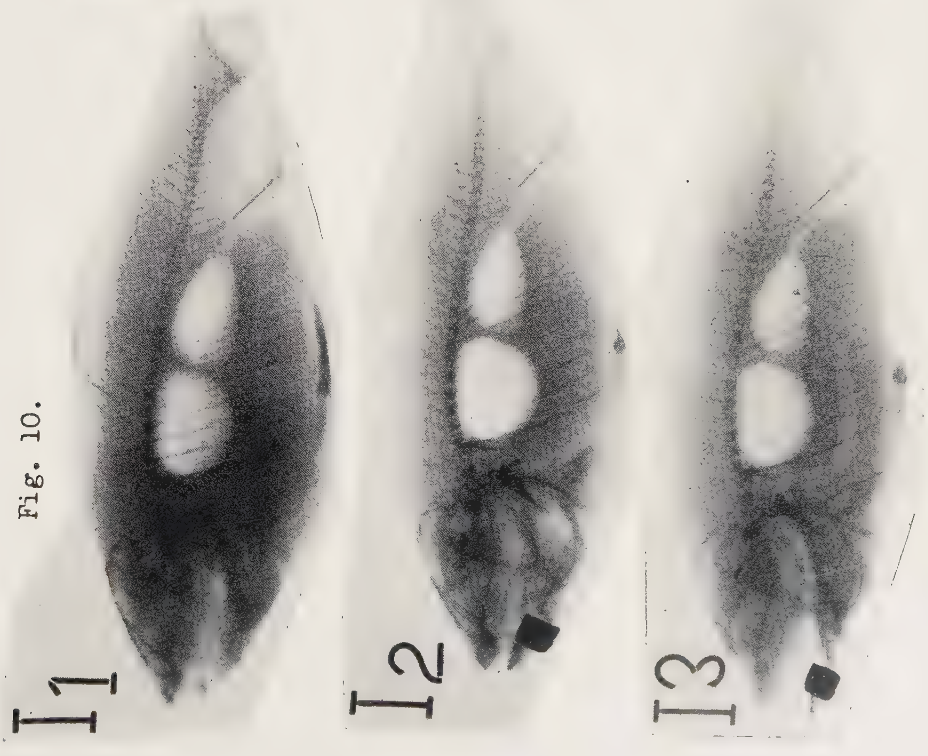


Fig. 10.

Explanation of Plate VI.

Fig. 12. After a week, when the size of the posterior lobe of the tailless fish appeared to have contracted, a weight was fixed under the posterior end of the body. The picture shows the resulting expansion of the posterior lobe again.

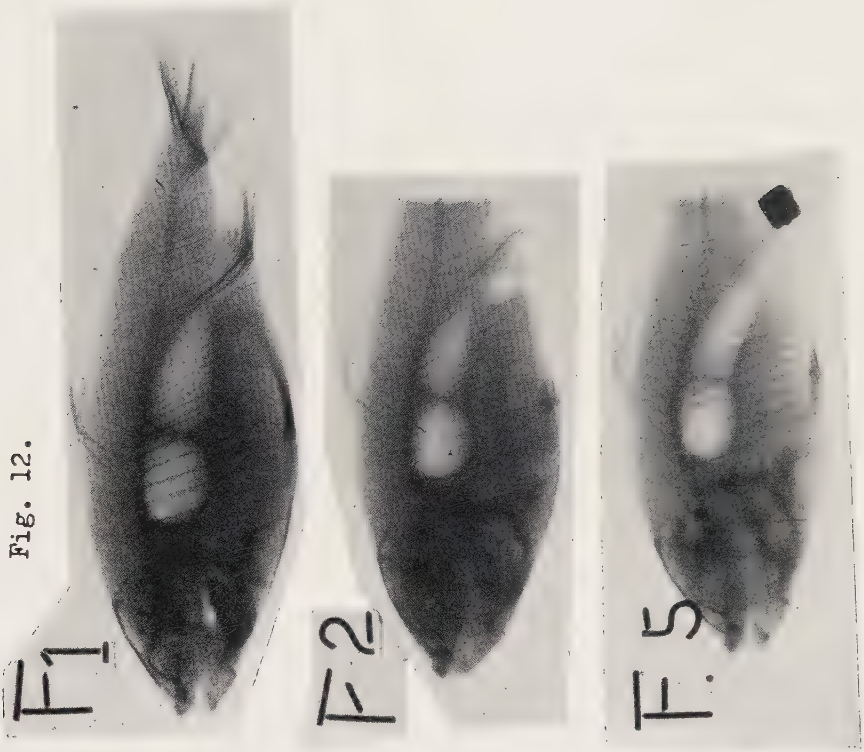


Fig. 12.

Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 4, No. 2, December 15, 1962

Four Species of Notodelphyoid Copepods newly found in Japan

Shigeko Ooishi

The present paper gives full descriptions on four species of Notodelphyoid copepods newly found in Japan. They comprise *Notodelphys agilis* Thorell *villosus* n. subsp., *Notodelphyopsis falciferus* Schellenberg, *Doropygus pulex* Thorell *pinguis* n. subsp. and *Doropygus rigidus* n. sp..

Notodelphys agilis Thorell *villosus* n. subsp.

Occurrence: 2 females in *Ascidia Zara* Oka, Tanabe Bay, Wakayama Prefecture, June 10, 1960; 2 females in same ascidian, Kesennuma Bay, Miyagi Prefecture, Aug. 22, 1962; 3 females in *Ciona intestinalis* (Linnaeus), Matoya Bay, Mie Prefecture, Jan. 26, 1961.

Female: Body (Fig. 1, A, B) depressed. Length, from fore end of prosome to tips of caudal rami, 2.5 mm. Body divisible into prosome, metasome and urosome. Prosome with a transverse orange band on dorsal face near hinder border and carrying appendages up to maxillipeds. Metasome composed of 4 limb-bearing segments; first 3 little modified, but 4th inflated to form a brood sac. Articulation between metasome and urosome lying in front of 5th thoracic segment which bears rudimentary legs. Urosome (Fig. 1, C) 5-segmented. Their proportional lengths from the first to the last are 3 : 4 : 3.5 : 3 : 3. Genital apparatus inconspicuous, lying on caudal margin of 1st urosomal segment on the midline.

Antennula (Fig. 1, D) 13-jointed, reaching about the middle of prosome. Basal 2 joints massive, remaining joints slender and successivly narrower towards the end. Setal formula: I, 3 setae; II, 17 setae; III, 6 setae; IV, 4 setae & 1 aesthetask; V, 4 setae; VI, 2 setae; VII, 2 setae; VIII, 1 setae & 1 aesthetask; IX, 1 seta; X, 1 seta; XI, 2 setae; XII, 2 setae & 1 aesthetask; XIII, 7 setae & 1 aesthetask.

Antenna (Fig. 1, E, F) 3-jointed. Proportional lengths of the joints from the basal to the apical are 4 : 3 : 4. Second and 3rd joints flexed against each other at a rightangle. Third joint narrow, about 4 times as long as wide, and ending in a stout curved claw, which is half as long as the concave side of the joint. Basal joint bears 2, long and short, inner setae and a short outer one on distal border. Second joint has a short seta on outer margin 2/3 distally from its base. Third joint carries 2 isolated setae and a group of 3 setae on outer margin at the points

Fig. 1, *Notodelphys agilis* Thorell *villossus* n. subsp., female. A, dorsal view; B, lateral view; C, urosome; D, antennula; E, antenna; F, apex of antenna; G, mandible; H, maxillula; I, maxilla; J, maxilliped. A, B × 25; C × 35; E, F × 185; D, G, H, I, J × 140.

1/4, 1/2 and 2/3 away from its base, and 2 curved rows of spinules on inner margin. Claw accompanied by 3 stiff, curved, blunt setae and same number of flexible short ones.

Mandible (Fig. 1, G) composed of 2-jointed protopodite, 2-jointed endopod and 1-jointed exopod. Coxa expanded medially into masticatory lamella marginated from before backward by 4 heavier teeth, 2 smaller ones, a short row of closely set denticles and 2 setules. Basis longer than wide, carrying a seta in the middle of inner margin. Basal joint of endopod furnished on medio-distal border with a row of 4 setae graded in length. Medio-distal margin of 2nd joint with 10 setae. Exopod elongate and bearing a few folds of integument on the surface. It carries 5 long setae on median and distal margins, most distal of these being longest and stoutest of all and exceeding 1.5 times the lengths of others which are subequal.

Maxillula (Fig. 1, H) consists of 2-jointed protopodite and 1-jointed rami. Epipodite represented by a seta and associated distally with a setule. Major endite enlarged, with 9 subequal setae on median margin. Secondary endite represented by a stout seta. Basis has 3 graded setae on outer margin. Endopod with 4 setae of graded lengths on its broadly truncate margin.

Maxilla (Fig. 1, I) 5-jointed. Basal joint strongly enlarged, occupying more than half the length of the limb and divided into 4 endites on median margin. First endite with 3 setae, 2nd with 1, 3rd with 2, and 4th with a basal setule besides with 2 longer setae. Second joint elongate medially into a falciform lobe, tipped by 2 slender setae. Succeeding 2 joints small in size, and each with a long slender seta at inner distal angle. Fifth joint smallest, with 4 slender apical setae.

Maxilliped (Fig. 1, J) 3-jointed. Basal joint more than half the entire length and armed on median margin with 9 setae forming 2 groups, of which the proximal consists of 4 setae and the distal of 5. Second joint rimmed with delicate hairs on median margin. Third joint provided on median margin with 1 spine with denticulated rim and at the end with 1 similar spine and 3 setae.

First swimming leg (Fig. 2, A) composed of 2-jointed protopodite and 3-jointed rami. Intercoxal plate well-developed and triangular. Coxa has on the medio-distal angle a long seta, which reaches terminal endopod joint. Lateral margin of basis diagonally reentrant, with a seta attaining to the end of 1st exopod joint. Basis bears on medio-distal angle a stout spine with distal denticulation besides with proximal ciliation and approximately reaching distal one third of 1st endopod joint. Endopod has 8 setae. Basal joint as long as rest joints combined together and bearing 1 moderately long median seta at distal one third of the median margin, 2nd with 1 seta on the same margin about the middle and 3rd with 3 median, 2 apical and 1 lateral setae. A short spinule presents only on 3rd joint at outer distal angle. Exopod furnished with 6 setae and 6 spines. Proximal 2 joints each with a spine at outer distal corner and a seta on inner border, and terminal joint with 3 lateral and 1 terminal spines and with 1 terminal and 3 median setae. All spines on lateral margin each accompanied by feeble spinule proximally. Proximal second spine on

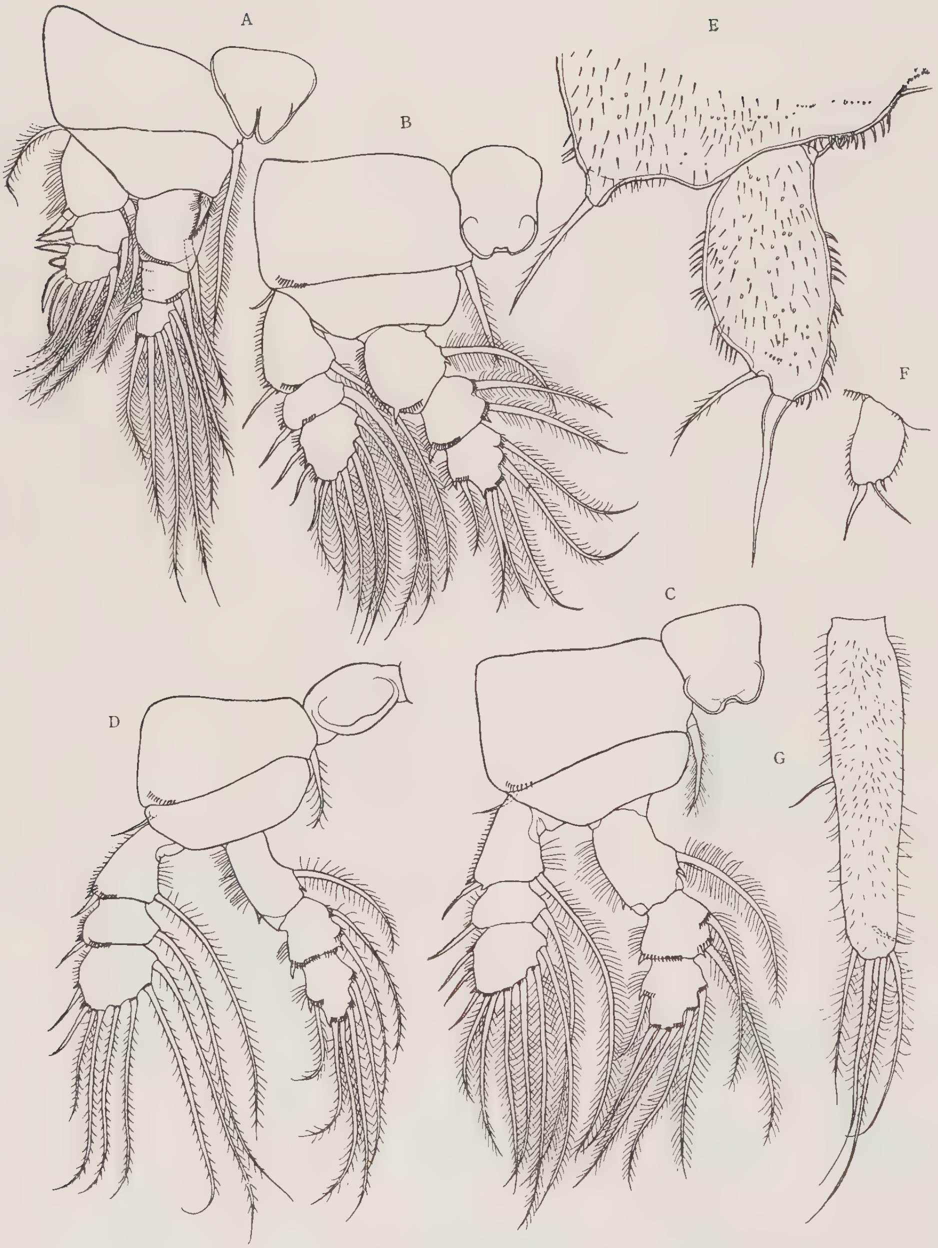


Fig. 2, *Notodelphys agilis* Thorell *villossus* n. subsp., female. A, 1st leg; B, 2nd leg; C, 3rd leg; D, 4th leg; E, 5th leg; F, apex of 5th leg; G, caudal ramus. A, B, C, D × 100; E × 270; F × 65; G × 70.

distal joint shortest, about half as long as the first.

Second swimming leg (Fig. 2, B) constructed by 2-jointed protopodite and 3-

jointed endo- and exopods. Intercoxal plate rectangular. Coxa bears at mediodistal corner a robust, but relatively short seta which reaches a little beyond the end of 1st endopod joint. Lateral seta of basis much reduced. Three joints of endopod each with a basal constriction. Endopod has 9 setae. Proximal joint with 1 median seta, 2nd joint with 2 median ones and distal joint with 3 median, 2 apical and 1 lateral setae. A short spinule present on 3 joints at outer distal angle and basal 2 at inner distal angle. All joints fringed by a short hairy row on outer margin. Exopod furnished with 5 spines and 8 setae. Two basal joints constricted at the base. Each bears a short slender lateral spine and a long median seta. Terminal joint somewhat less constricted at the base, tapering distally, and furnished with 3 lateral spines and 2 apical and 4 median setae. All the spines slender and setiform aspect and associated at the base with a tiny spinule.

Third swimming leg (Fig. 2, C) consists of 2-jointed protopodite and 3-jointed rami. Coxal seta short and slender. Basal joint of endopod longer but narrower than in preceding leg. Otherwise, armature of both the rami as in that of 2nd leg.

Fourth swimming leg (Fig. 2, D) relatively smaller than preceding leg in size. Intercoxal plate shorter than wide. Armature differs from that of 3rd leg in that the member of setae on terminal endopod joint and that of spines on distal exopod joint are decreased by one. Thus, endopod has 8 setae and exopod 4 spines and 8 setae.

Fifth leg (Fig. 2, E) 2-jointed. The basal joint broad and produced at lateral corner into a short digitiform process, tipped by a short slender seta. Second joint ovate, with a terminal spine and a short flexible subterminal seta on lateral margin. Only left leg with a short but stout subterminal, additional spinule on median margin (Fig. 2, F). Legs of both sides rimmed with fine spinules besides with surfacial ones.

Caudal ramus (Fig. 2, G) about 4.5 times as long as wide, twice as long as anal segment, and terminating in 4 setae. Central two of these longer than others. Outer margin with a short seta about the middle and dorsal surface with another near terminal end.

Male: Unrepresented in the present collection.

Remarks: Of all the species of *Notodelphys*, *N. agilis* THORELL is characterized by the caudal ramus attaining twice the length of anal segment and by the site of its lateral seta which is inserted in the middle of the outer margin. The fifth legs of this species is said, according to SARS (1921), to have a rather broad proximal joint bearing short digitiform process. The present form appears, therefore, to fall within the confine of *N. agilis* in these points. It is, however, differentiated from *N. agilis* by having the caudal ramus ciliated on both sides and having fine marginal denticles on both the joints of the 5th legs, since the caudal ramus of *N. agilis* is ciliated only along outer margin (SARS, 1921 and GOTTO, 1960) and the proximal joint of the 5th legs is non-hairy (SARS, 1921). Further differences, though slight, exist in the segmentation of antennula and in the setation of antennula, antenna

and mouth parts. Some of the figures of appendages given by Sars and Brady (1878), however, do not appear properly represent the constitution to be found in *N. agilis*. Such being the case, it is not an easy task to find the specific limit of *N. agilis*, and in so far as the new form does not completely agree with this species, though nearly allied, it seems to me appropriate, for the present, to place it in the rank of subspecies of *N. agilis*.

Notodelphyopsis falciferus Schellenberg

Notodelphyopsis falciferus Schellenberg, 1922, pp. 237–239, Figs. 17–20.

Occurrence: 6 females in *Ascidia zara* Oka, Tanabe Bay, Wakayama Prefecture, June, 9, 1960, 2 females in *Ciona intestinalis* (Linnaeus), Matoya Bay, Mie Prefecture, Jan. 26, 1961.

Female: Body (Fig. 3, A, B) depressed and straightened, though vaulted in the region of brood pouch. Average length of 5 specimens, 3.2 mm. Regions in front and in the rear of brood sac strongly frailed and slender. Prosome small in size. Metasome consists of 3 small segments and prominently enlarged 4th segment, each with a pair of swimming legs with normal structure. Prosome and 2nd and 3rd metasomal segments produced at postero-lateral angles into a short acute lobe. Brood sac ovoidal, longer than wide, and about 2.3 times as long as preceding region. Fifth legs at posterior extremity of brood sac. Urosome (Fig. 4, G) 4-segmented; 1st segment formed by fusion of last thoracic and first abdominal somites. Genitatal apparatus located at anterior one third of 1st urosomal segment. Proportional lengths of urosomal segments from before backward are 2.4: 2.1: 2: 2. Caudal ramus about 1.7 times as long as urosome. Rostrum (Fig. 3, C) rectangular in dorsal aspect and wider than long, slightly widening distally.

Antennula (Fig. 3, D, E, F) 7-jointed, long and slender, reaching posterior margin of 3rd thoracic segment. First joint wedge-shaped, shortest of all, but greatest in diameter. Remaining 6 joints much longer than wide. Proportional lengths of 7 joints from proximal to distal as 1: 1.7: 2.2: 1.7: 2.3: 2.4: 1.7. Each of them with short plumose setae. Setal formula: I, 7; II, 12; III, 4; IV, 4; V, 4; VI, 1; VII, 12.

Antenna (Fig. 3, G, H) 2-jointed. Ratio of lengths between 1st and 2nd as 1.2: 1. First joint more than once wider than 2nd joint, narrowed distally to form together with 2nd joint an elbow like articulation, and carrying 2 long setae on inner margin at distal 2/5. Second joint linear, slender, having a short seta on outer margin at proximal quarter and 3 setae at distal one third. Inner margin bears 2 rows of spinules. Terminal hook curved, slender and associated with 3 blunt and 3 slenderer setae.

Mandible (Fig. 3. I, J) has 2-jointed protopodite, surmounted by 2-jointed endopod and 1-jointed exopod. Masticatory edge (Fig. 3, J) has 4 stronger and 2 feebler teeth, a wide truncate lobe and 2 isolated proximal setules. Basis has a single seta at about the distal one third of the median margin. First endopod joint

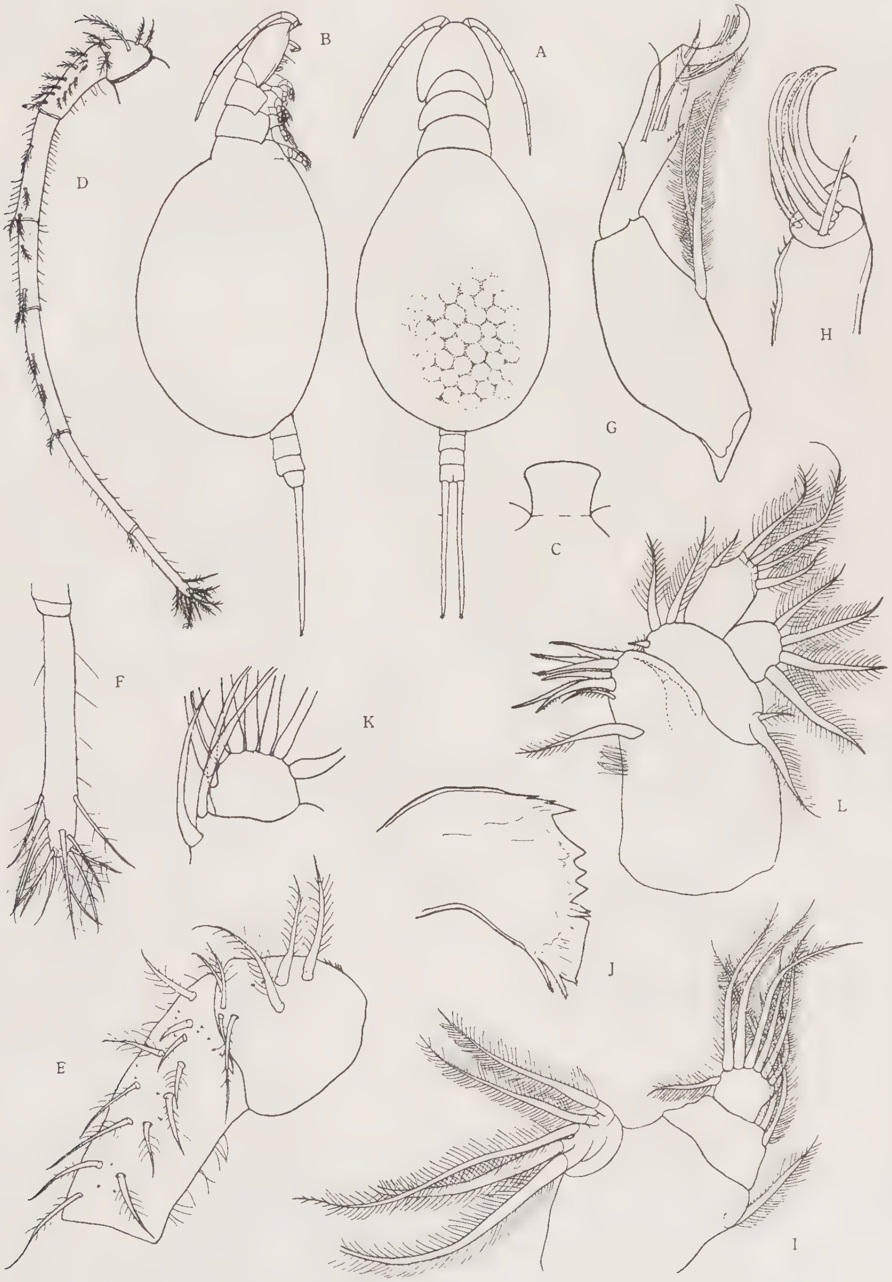


Fig. 3, *Notodelphyopsis falciferus* SCHELLENBERG, female. A, dorsal view; B, lateral view; C, rostrum; D, antennula; E, same, 1st and 2nd joints; F, same, 7th joint; G, antenna, left; H, same, apex; I, mandible; J, same, masticatory plate; K, same, inside of endopod; L, maxillula. A, B × 25; C, D × 100; E, F, J, K, L × 400; G, I × 270; H × 530.

has 2 setae near at inner distal angle and second joint (Fig. 3, K) surrounded by 8

setae around distal margin. Exopod depressed, showing an appearance of a short truncate cone, surmounted with 5 setae. Basal two of these are longer, stouter than others and twice as long as the rest of them both in length and width.

Maxillula (Fig. 3, L) has 2-jointed protopodite, and 1-jointed endopod and exopod. Coxa bears 2 expansions which represent endites. Larger proximal one of these has a median row of 8 setae, basal one of which is a short distance removed from others. Second endite is a feebly developed seta-like outgrowth. Epipodite has 2 long and short setae. Basis with a short proximal and 2 long distal setae on median border. Endopod longer than wide, with 5 setae on distal margin, of which outer 2 are shorter than others, and another shorter one on median margin at distal one third. Exopod tipped by 4 long, subequal setae.

Maxilla (Fig. 4, A) 5-jointed. Median margin of large basal joint produced into 4 endites showing varying extent of development. First of these with 3 setae, 2nd with one, 3rd and 4th with 2. Second joint furnished on median border with a long, stout spine, which is associated at the base with a slenderer and again feebler setae. Third and 4th joints bearing a long median slender seta. Fifth joint small, terminating in 3 feeble setae.

Maxilliped (Fig. 4, B) 3-jointed. Basal joint longest of all and fringed by 2 groups of setae; basal group consisting of 4 setae and terminal group of 5 setae. Second joint is relatively large in size, with its middle region somewhat inflated and fringed by fine hairs on median margin. Third joint small, about 1/3 as long as 2nd, and ending in 2 unequal setae.

First swimming leg (Fig. 4, C) has 2-jointed protopodite and 3-jointed rami. Intercoxal plate triangular in outline. Median coxal seta moderately long, reaching the end of 2nd endopod joint. Basis has a long, stout spine at medio-distal angle and a short seta on lateral margin near the base. First endopod joint large in size as long as rest joints combined together. This and next joints each with a median seta and 3rd joint with 3 median, 2 apical and 1 lateral setae. Exopod slightly flexed medially, and smaller than endopod in size. First joint largest of all and with a curved lateral spine. Second joint smallest, with a curved lateral spine and a median seta. Third joint with 3 lateral spines, besides with 1 terminal and 4 median setae. Spine on basal joint stoutest.

Second swimming legs (Fig. 4, D) are connected with each other by a reduced intercoxal plate. Setule at medio-distal corner of coxa rudimentary. Both rami 3-jointed. Endopod slightly shorter than exopod and armed with 9 setae; proximal joint with one, 2nd with 2 on median side and 3rd with 3 median, 2 apical and 1 lateral setae. All joints rimmed with delicate hairs on lateral side. Exopod has 6 spines and 6 setae; 1st joint with 1 stout curved spine at outer distal angle, 2nd with similar one at similar point and 1 seta at distal one third of median margin, and 3rd with 3 outer and 1 apical spines as well as 4 median and 1 apical setae. Spines on this last joint straight and blunt.

Third and 4th swimming legs (Fig. 4, E, F) resemble 2nd legs in structure.

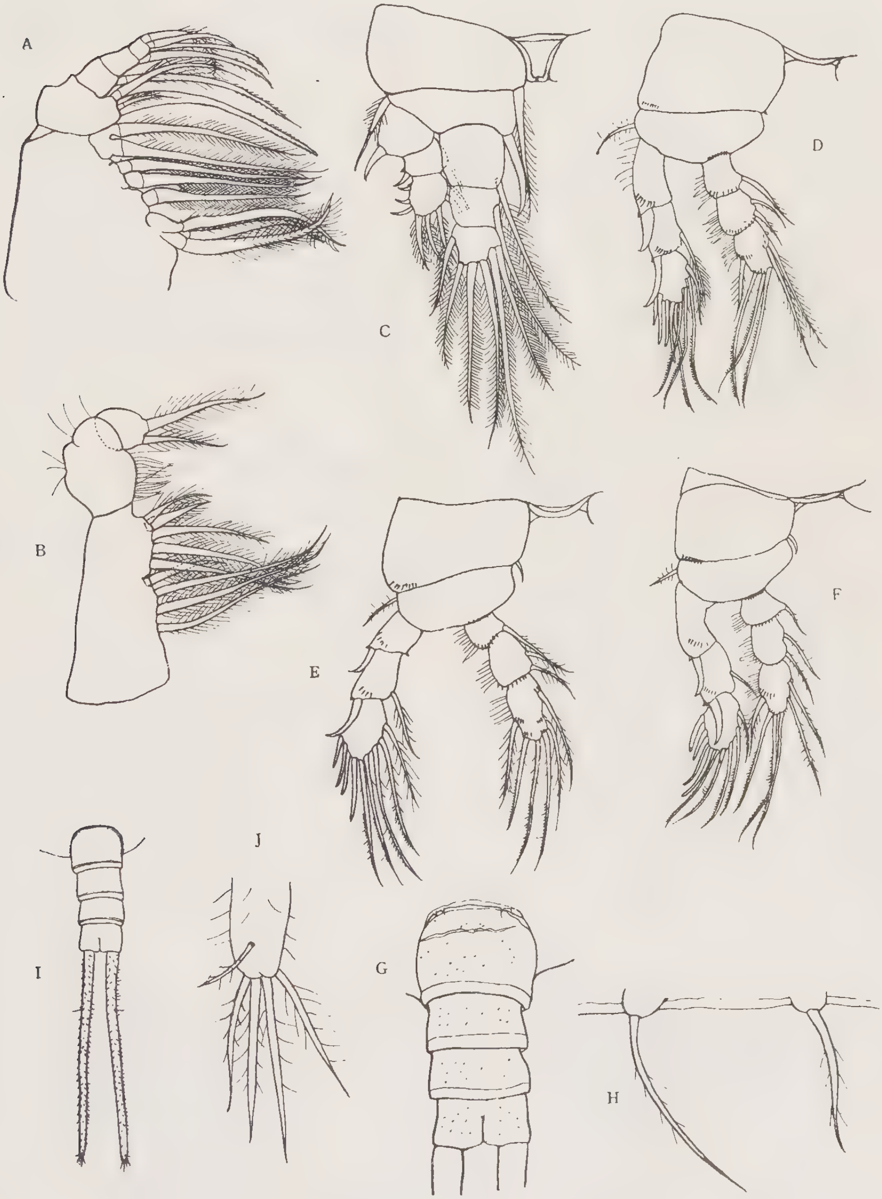


Fig. 4, *Notodelphyopsis falciferus* SCHELLENBERG, female. A, maxilla; B, maxilliped; C, 1st leg; D, 2nd leg; E, 3rd leg; F, 4th leg; G, urosome; H, 5th leg; I, urosome and caudal rami; J, apex of caudal ramus, dorsal view. A × 340; B, 360; C, D, E, F × 140; G × 75; I × 37; H × 750; J × 435.

Fifth leg (Fig. 4, G, H) represented by two pairs of slight bulges disposed sidewise at the base of urosome, and tipped by a short setule.

Caudal ramus (Fig. 4, I, J) elongate and slender, 22 times as long as wide and armed with 6 short setae. Four of them disposed side by side at the end of ramus,

another located on the outer side at the proximal quarter and again another on dorsal surface and a little removed forward from apical group of setae. Both the margins of ramus ciliated.

Male: Unrepresented in the collection.

Remarks: The animal is straight and strongly frail. The author has found general conforms in essential points with SCHELLENBERG's original description, except in the constitution of antennula, maxilliped and the 5th leg. Although he says of antennula as being 8-jointed, maxilliped as 2-jointed and 5th legs as lacking, the present specimens possess the distinctly 7-jointed antennula, the 3-jointed maxilliped and the 5th legs. Reexamination of SCHELLENBERG's specimen with respect to these points are desirable. At present, the author confines herself to assign the present specimens to the known species.

Doropygus pulex THORELL *pinguis* n. subsp.

Occurrence: 3 females, Gokasho Bay, Mie Prefecture, June 25, 1960; 4 females, Ago Bay, Mie Prefecture; June, 26, 1960; 2 females, Tanabe Bay, June, 10, 1960; 50 females, Matoya Bay, Mie Prefecture, Jan. 26, 1961.

Host: *Styela plicata* (LESUEUR).

Female: Body (Fig. 5, A) 2.7 mm long from the apex of prosome to the end of caudal ramus, compressed and somewhat curved ventrally. Prosome carries appendages up to maxillipeds. Metasome consists of first 4 limb-bearing segments. Fourth segment accomodates large, prominent brood sac. Articulation of metasome and urosome represented by the boundary between 4th and 5th thoracic segments. Urosome (Fig. 5, B) composed of 6 segments, including 5th thoracic segment. Second segment with valval aperture at anterior quarter and sclerotized seminal tubes issuing from the aperture. Proportional lengths of segments as 4: 4: 7: 6: 5: 5. Rostrum produced ventrally into an acute triangular lobe.

Antennula (Fig. 5, C) 7-jointed, with rather feeble setae. Two basal joints larger than the rest and expanded. Second joint accompanying at its base a triangular setiferous lobe. Terminal joint elongate, presumably made up of 3 coalesced joints, which are indicated by marginal indentations and by disposition of setae. Number of setae present on joints are: I, 3; II, 13+1 hook; III, 5; IV, 4; V, 3; VI, 2+1 aesthetask; VII, 12+2 aesthetasks.

Antenna (Fig. 5, D, E) 3-jointed, and slender. Proportional lengths of joints from basal to apical as 7: 4.5: 6. Proximal 2 joints non-setose. Terminal joint has a minute setule on outer face at distal one quarter and 2 farther distally. It is surmounted by curved hook which reaches nearly half of its own length and bears 3 stiff, blunt setae associated with another tiny one.

Mandible (Fig. 5, F) composed of 2-jointed protopodite, 2-jointed endopod and unjointed exopod. Coxa divided on gnathal margin into 4 larger and 1 smaller teeth, a row of thickly arranged tiny denticles and carrying 2 setules on hinder

Fig. 5, *Doropygus pulex* THORELL *pinguis* n. subsp., female. A, lateral view; B, urosome, ventral view; C, antennula; D, antenna; E, same, apex; F, mandible; G, maxillula; H, maxilla; I, maxilliped. A × 25; B × 35; C, G, H, I × 270; D × 140; E × 400; F × 175.

margin. Basis has a seta on median margin near the end. First endopod joint carries 4 setae graded in length on median margin; most distal one much longer than others. Second joint circumscribed by 8 setae around its tip. Exopod relatively well-developed with several integumental folds on the surface and with 5 setae along median and distal border; most distal of these slender, and half as long as the rest 4 which are subequal. In some cases the named seta is reduced to a minute setule.

Maxillula (Fig. 5, G) consists of 2-jointed protopodite and 1-jointed rami. Proximal endite of coxa furnished with 9 subequal setae. Distal endite represented by a narrow lobe resembling a seta. Basis armed with 3 graded setae on median side. Both endopod and exopod directed laterally. The former smaller and with 2 terminal setae; the latter with 4 of these, of which proximal most is longer than others. Epipodite rudimentary, with a tiny setule besides with ordinary seta.

Maxilla (Fig. 5, H) 5-jointed. Basal joint longer than rest joints combined together and with 4 endites. First of these with 3 subequal setae, 2nd with one, 3rd with 2 and 4th with 2 equal setae associated with a reduced minute setule. Second joint has 2 setae and a vestigial setule; distal seta shorter but more rigid than others and sparcely hairy. Third and 4th joints each with a single long seta. Terminal joint carries 2 short apical and 1 long median setae.

Maxilliped (Fig. 5, I) 2-jointed. Basal joint ornamented by 2 groups of marginal and surfacial setae; proximal group comprising 5 setae and the distal 4. Distal joint very short, tipped by 2 long stout subequal setae.

First swimming leg (Fig. 6, A) consits of 2-jointed protopodite and 3-jointed rami. Intercoxal plate trapezoid. Inner seta of coxa long, reaching far beyond tip of endopod. Basis has a feeble seta at outer distal angle and a stout spine at inner distal angle. Setae on endopod 8 in number. Basal 2 joints wider than long, each carrying a single median seta. Third joint with 3 median, 2 terminal and 1 lateral setae. Exopod with 6 spines and 6 setae; 1 large outer spine and 1 inner seta on basal 2 joints, and 3 outer and 1 apical spines, 1 apical and 3 inner setae on distal joint.

Second leg (Fig. 6, B) with 2-jointed protopodite and endopodite and 3-jointed exopodite. Median seta of coxa reaches the middle of distal joint of endopod. Basis has a reduced lateral setule. Endopod slightly shorter than exopod and furnished with 9 setae; basal joint half as long as rest joints and provided with a median seta; terminal joint with the indication of suppressed subdivision, and with 4 median, 3 apical and 1 lateral setae. Each of basal 2 joints of exopod armed with 1 lateral setiform spine and 1 median seta. Apical joint with 3 lateral and 1 apical setiform spines, and 1 apical and 4 median setae.

Third swimming leg (Fig. 6, C) as in the second.

Fourth swimming leg (Fig. 6, D) conforms to the precedings, except for that setae on distal endopod joint and setiform spines on terminal exopod joint are smaller in number by one, and median seta of coxa is much shorter.

Fifth leg (Fig. 6, E) 2-jointed. Basal joint wider than long, indistinctly articu-

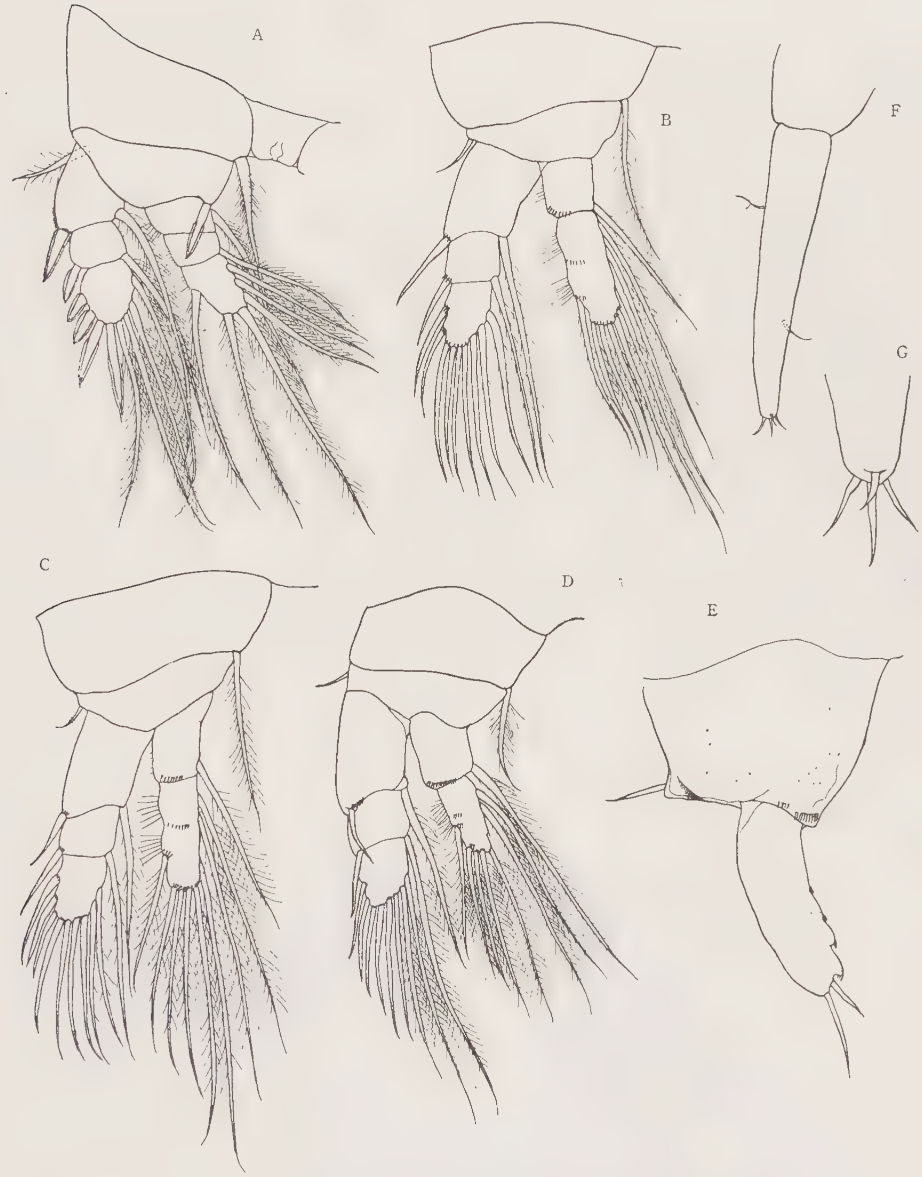


Fig. 6, *Doropygus pulex* THORELL *pinguis* n. subsp., female. A, 1st leg; B, 2nd leg; C, 3rd leg; D, 4th leg; E, 5th leg; F, caudal ramus; G, same, apex. A, B, C, D, F × 140; E × 195; G × 470.

lated to the body, and with a small short seta on the distal lateral corner and a row of denticles on medio-distal angle. Second joint about thrice as long as the greatest width, half as wide as distal border of basal joint, and ending in an outer short and an inner stouter shorter setae. Inner border raised into 4 small bulges, each of which is furnished with a row of fine denticles.

Caudal ramus (Fig. 6, F, G) slender, relatively long, and tapering distally. It is about 5.4 times as long as wide, twice as long as anal segment, tipped by 4 minute subequal setae, and carrying on lateral side at proximal one third a reduced seta and a similar one on dorsal face one third proximad from the tip.

Male: Unrepresented in the collection.

Remarks: This form was found only in a sole host, *Styela plicata* (Lesueur), in which 5 or 6 individuals lived. In the Inland Sea (Oomishima, Ehime Prefecture) it was never found in the same host despite the careful examination of about 100 specimens. This appears to indicate the presence of certain peculiarities between the host-parasite specialization and the locality. Illg and Dudley (1961) described in full *Doropygus pulex* from *Microcosmus sulcatus*. *Styela* parasite differs from *D. pulex* in some minor details: The body is somewhat more stumpy than in *pulex*, the exopod of the mandible has an additional short apical seta, the maxilliped consists of 2 joints, and the basal joint of the 5th leg is broader, having truncate distal margin. In the specimens of *pulex* from Woods Hole, the exopod of the mandible has 4 long and 1 minute apical setae as in the new subspecies. Frorida specimens have 9-jointed antennula, which is composed of 7 joints in the parasites from *Styela* and *Microcosmus*. Such being the case, it seems better to differentiate the Japanese form from *D. pulex* as its new subspecies in order to avoid a confusion.

Doropygus rigidus n. sp.

Occurrence: One female in *Herdmania momus* (Savigny), Tanabe Bay, Wakayama Prefecture, June 23, 1960; 5 females in *Cnemidocarpa areolata* (Linnaeus), Matoya Bay, Mie Prefecture, Jan. 26, 1961.

Female: Length measured along body axis 3 mm. Body form (Fig. 7, A, B) variable from a compressed one to a depressed one, and enclosed by strongly chitinized integument, on which very minute spinules are found. It is divisible into prosome, 4-segmented metasome and 6-segmented urosome. Prosome and 2nd to 3rd metasomal segments has well-defined pleura with thick marginal ridge. Prosome bears appendages up to maxillipeds. Last metasome segment forming a strongly inflated marsupium. Boundary of meta- and urosomes represented by articulation between 4th thoracic and 5th segments. Urosome (Fig. 7, C) relatively slender, proportional lengths of its segments measured along ventral line as 1: 1.7: 2: 2.2: 1.5: 1. Genital apparatus with vulva on the midline of 2nd segment. Rostrum obtusely triangular, curved ventrally between both antennulae, and with free margin especially rigid.

Nine-jointed antennula (Fig. 7, D) with basal joint elongate and suceeding joint somewhat shorter and expanded into a lamella. Distal 7 joints short and slender. Setal formula: I, 3; II, 14; III, 5; IV, 3; V, 5; VI, 3; VII, 2; VIII, 1; IX, 8. In general, those setae are long, and non-hairy in some of them.

Antenna (Fig. 7, E) slender, 3-jointed and with setae much reduced. Propor-

Fig. 7, *Doropygus rigidus* n. sp., female. A, lateral view; B, dorsal view; C, urosome; D, antennula; E, antenna; F, same, apex; G, same, outside; H, mandible; I, palp of mandible; J, maxillula. A, B × 27; C × 44; D, E, H × 140; F, G, I, J × 270.

tional lengths of joints from basal to distal: 2.4: 1.3: 2.3. Basal 2 joints without any armature. Third joint (Fig. 7, F, G) ending in a short and strongly curved hook, which is 1/5 as long as its own length and associated with 2 curved stiff blunt and 4 feeble short setae. It bears further 2 setae on outer surface near the end.

Mandible (Fig. 7, H) consists of a coxa, which is produced medially into toothed masticatory plate, and basis, from which 2-jointed endopod and 1-jointed exopod arise. Masticatory lamella (Fig. 7, I) with 4 major teeth, 2 minor ones, followed by a row of thickly set denticles and 2 hinder setules. Basis broad, with a seta on median margin near distal end. First joint of endopod wider than long, carrying 4 setae graded in length on median margin near the end. Second joint elongate, twice as long as wide, and furnished with 9 marginal setae forming groups of 6 median and 3 apical ones. Exopod elongate, having 5 long subequal setae on median and distal margins and integumental folds on the surface.

Maxillula (Fig. 7, J) with 2-jointed protopodite and 1-jointed rami. Major endite of coxa furnished with 9 graded setae on median margin. Terminal endite a small, seta-like projection. Basis armed with 3 setae of graded lengths on inner margin. Endopod with 3 long setae, on inner margin extending from its base to the apex. Exopod with 4 unequal marginal setae; proximal most the longest of all. Epipodite represented by an ordinary proximal and tiny distal setae.

Maxilla (Fig. 8, A) relatively narrow, 5-jointed and straightened. Basal joint about as long as remaining joints combined together, and with 4 endites. First endite carrying 3 subequal setae, 2nd 1, 3rd 2 and 4th 2 and 1 tiny, more proximal setae. Second joint broader than long, with 2 long and a short proximal setae on median margin. Third joint as long as wide, only with a long seta at medio-distal angle. Fourth joint longer than wide and with a long seta at medio-distal corner. Fifth joint small, with 3 setae and a feebler proximal setule.

Maxilliped (Fig. 8, B) 2-jointed. Basal joint quadrate and furnished on median margin with 9 setae which are disposed to form 2 groups of proximal 4 and distal 5. Apical joint short, ending in 2 long subequal, stout setae.

Swimming legs are characteristic in that both the rami are bent towards the mid-ventral line. Armature of their rami are all setiform in constitution, except in 1st swimming legs, and are considerably long and stiff.

First swimming leg (Fig. 8, C) with 2-jointed protopodite and 3-jointed rami. Intercoxal plate subtriangular. Median seta of coxa reaches the middle of 3rd endopod joint. Basis with a short seta on lateral margin and a stout spine at medio-distal corner. Endopod has 8 setae; 1 on each of first 2 joints on median margin near distal end, and 3 median, 2 apical and 1 lateral setae on terminal joint. Exopod carries 5 spines and 7 setae: Basal 2 joints each with 1 lateral spine and 1 median seta, and distal joint with 3 lateral spines, and 2 apical and 3 median setae. Spine on basal joint longest of all.

Second swimming leg (Fig. 8, D) consists of 2-jointed protopodite, 2-jointed

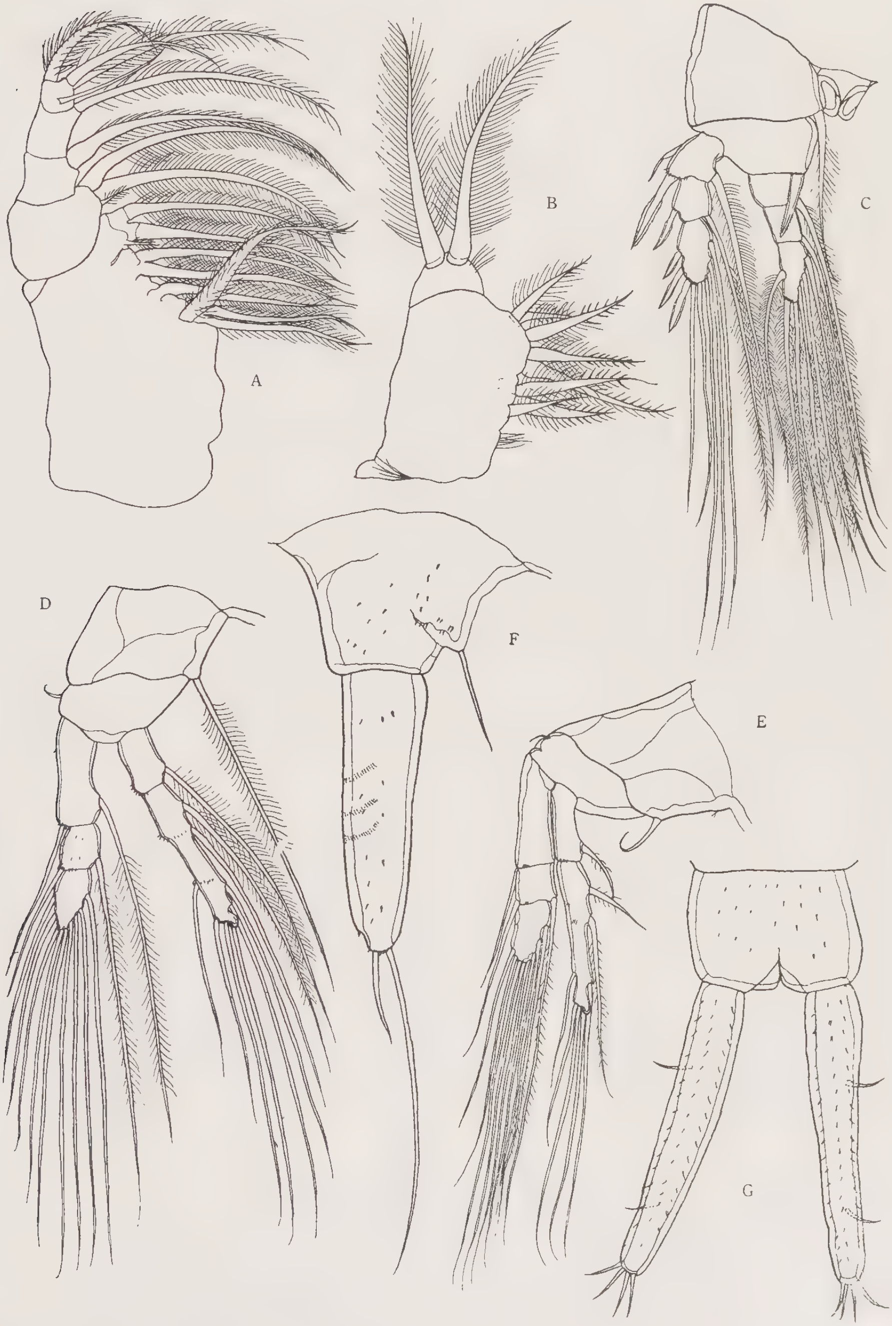


Fig. 8, *Doropygus rigidus* n. sp., female. A, maxilla; B, maxilliped; C, 1st leg; D, 2nd leg; E, 4th leg; F, 5th leg; G, caudal rami. A, B, F × 270; C, D, E × 100; G × 145.

endopod and 3-jointed exopod. Intercoxal plate reduced. Median seta of coxa one

and half times as long as endopod. Lateral seta of basis very minute. Endopod elongate, as long as exopod and furnished with 9 setae. Basal joint occupying 1/3 of ramus and having 1 seta near distal one third of its median side. Terminal joint indicative of coalescence of 2 joints, and provided with 4 median, 2 apical and 2 lateral setae. Exopod has 13 setae; 1 on both sides of each of basal 2 joints, and 3 lateral, 2 terminal and 4 median on 3rd joint.

Third swimming leg consists of 2-jointed protopodite and 3-jointed rami. Exopod slightly shorter than endopod and the proportion in lengths is 6: 7. Otherwise, as in the preceding leg.

Fourth swinmming leg (Fig. 8, E) with a reduced median non-hairy coxal setule and relatively smaller than preceding leg in size. Armature differing from 3rd leg in that member of setae on distal endopod joint and that of setae both on basal and distal exopod joints are smaller in number by one. Thus, endopod has 8 setae and exopod 11 setae.

Fifth leg (Fig. 8, F) consists of 2 well-defined joints with proportional lengths as 1: 1.8. Lateral mergin of basal joint has near the end a small projection tipped by a short seta. Second joint has 1 short median and 1 long lateral setae; the latter 3.5 times as long as the former and exceeding the length of the joint. It bears 3 transvers rows of fine spinules on median side.

Caudal ramus (Fig. 8, G) long, 2.8 times as long as anal segment. It slightly tapers toward the tip, ends in 4 minute subequal setules and carries 2 setules on dorsal side, one at proximal three quarter of its length and another at one third and somewhat laterally.

Male: Unrepresented in the present collection.

Remarks: The present form may be easily distinguishable from any of the known species of *Doropygus* by its robust body covered by hard integument showing rigid appearance, which is emphasized in the prosomal and the second and third metasomal pleura. Besides, all the appendages and their armature are heavily sclerotized. Although this form has certain resembrances to *D. kerguelensis* in the possession of 3 setae on maxillular endopod and in the condition of setae on the second joint of maxilla and on the exopod of the second to fourth legs, it differs in its rigid body and in the setal formula of other appendages.

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Studies on the Marine Fouling Communities

I. Development of a Fouling Community

Tatuo Kawahara

(With Plates I–II)

Although the author was engaged with ecological studies on the marine fouling organisms in Amakusa Marine Biological Laboratory of Kyūshū University as well as in Faculty of Fisheries, Prefectural University of Mie for long years, he has not yet had the opportunity of publishing the greater part of the results for various reasons. The present article is the first of the serial works which the author is anxious to publish from now on.

So far as a fouling community is constructed by various groups of organisms, much complicated phenomena are expected to be involved in its development, which may be a total sum of varieties of characters of the constituents. The present study aims to make clear the various phenomena associated with the development of such community.

Before going further I should like to express my great indebtedness to Prof. S. M. Shiino, Dean of our Faculty, who kindly read and corrected the manuscript. Particular thanks are due to Dr. H. Ohshima, Member of Academy and Emeritus Professor of Kyūshū University, for his kindness in directing me to this interesting field of study and in leading me in Zoological Laboratory of Kyūshū University.

1. Method and locality

Through an experience in some of the author's preliminary experiments, the community developing on a substratum set in the sea was examined at intervals of about every 5 days.

As a substratum for the fouling organisms, the concrete block of the size 30 cm long, 30 cm wide and 2 cm thick was prepared. It was suspended by two ropes from a raft and maintained one meter beneath the sea surface. One of the block surfaces largest in area was faced southward and the community developing on this face was chiefly made the material. For the convenience of description the block surface was divided as shown in Fig. 1.

The raft was set afloat at a point 50 m apart from the front shore of Amakusa Marine Biological Laboratory and was fastened to four anchors so as to be kept in

a constant direction. The test blocks hung from the raft and immersed in the sea were brought into the laboratory aquaium at regular intervals, and the organisms grown over it were numbered by the aid of a quadrat. After examination, the

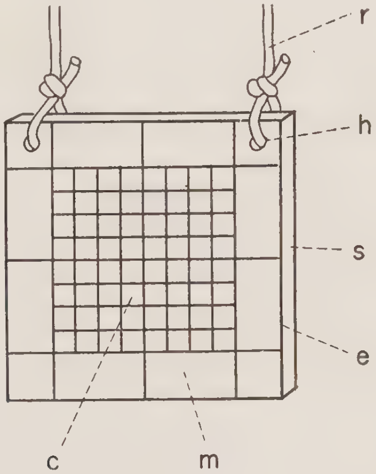

Fig. 1. Terminology of the test block. c, central region; e, edge; h, hole; m, marginal region; r, rope; s, side.

block was put back in the original place in the sea so that a perpetual attachment of organism is not discontinued.

The glass aquarium used for examination of the block was 60 cm × 40 cm in bottom area and 45 cm in height, and was supplied with running sea water so as to keep the organisms healthy. The test block surface on which the community to be examined grew was closely applied parallel to the side of the aquarium. Between them a glass quadrat was inserted in order to afford facility for ascertaining the site and growth of organisms. The quadrat was partitioned into every 2.5 cm square.

By illumination with two 100 w lamps, the sites of growing organisms on the block thus placed in the aquarium were transcribed on a section-paper. An exami-

Table 1.
Water and air temperatures in °C at the station (averages of the years from 1944 to 1948).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Water	13.3	13.0	14.6	16.2	19.0	22.7	25.3	27.1	25.0	21.7	19.0	16.1
Air	7.0	7.9	13.2	15.9	20.1	23.2	27.2	28.3	25.5	20.4	16.7	11.6

nation necessitating a precision was made by the aid of a magnifier or a binocular microscope. Barnacles of the size smaller than 3 mm in carinorostral diameter were measured with the micrometer and larger ones were with dividers.

The station of the experiment was the westpart of the Inlet of Tomoe, which

is located to the west of Tomioka Bay (32° 32′ N, 130° 2′ E) and had a depth of 10 m and mud bottom. At this spot the tidal range attained 3.3 m in Spring and the sea was ordinarily very calm. Washed by a branch of Tsushima Warm Current, the climatic condition in this district is quite mild (Table 1).

2. Observation on the development of a fouling community

Successive changes in the outward look of a fouling community, the development of which was initiated in winter (January 31), will be described first.

The first month. 20 days after the immersion of test block (February 20): The surface of the test block was still clean from any stain visible to the naked eye. 36th day (March 7): The surface was tinged with pale yellowish colour owing to the attachment and growth of diatoms and other minute algae. Small colonies of *Clytia* were found in a small number on the edges of the block. Amphipods built their dwelling tubes on the ropes hanging the block, though none was found on the block surface. Four individuals of *Spirorbis* attached themselves to the surface (Table 2).

The second month. 42nd day (March 13): The minute algae growing on the block was covered by silt, so that the block surface presented dim appearance. Both hydroids and amphipods were scarecely increased in their number. *Spirorbis* and *Balanus trigonus* were attached to the surface anew both in a single number. 51st day (March 22): No appreciable change was observable on the surface except for the additional attachment of four *Spirorbis.* 61st day (April 1): Fouling by minute algae was further advanced. They were increased in their height to a certain extent and became brownish in colour. Hydroids comprising *Obelia* (20% in volume) and *Clytia* (80%) were steadily growing on the edges of the block. Amphipods began to build their dwelling tubes in the marginal region of the surface. Two of *Spirorbis* were lost, but four were substituted. *Balanus trigonus* found about 20 days before was found dead, remaining still in a small size.

The third month. 71st day (April 11): The surface was heavily fouled with diatoms and minute algae which were thickly covered by silt. Amphipod tubes invaded the central region of the surface, making the fouling further serious. All animals having attached themselves by this time were buried within the thick algal fouling. Two *Spirorbis* and 11 *Balanus* were added, but *Bugula neritina* present on April 6 had disappeared (Fig. 2A; Pl. I, Fig. 1). 82nd day (April 22): Fouled surface was thickly and completely covered by growing hydroids. Additions to the community were nine *Balanus*, two *Spirorbis*, one *Bugula neritina* and one *Bugula californica.* Of these, the last species was not found until then. Formerly attached *Balanus* was making a steady growth, and became dominant over others, even *Spirorbis* in this community (Fig. 2B; Pl. I, Fig. 2). 92nd day (May 2): Hydroids and minute algae having grown over the surface began to wither, so that the new attachment of animals was promoted and their sites were easily recognizable. Fiftyeight indi-

viduals of *Balanus trigonus* and two individuals of *Spirorbis* arrived anew. Members new to the community were three *Balanus tintinnabulum rosa* and one *Watersipora cucullata*. *Bugula neritina* once declined late in April restored its vitality, renewing its

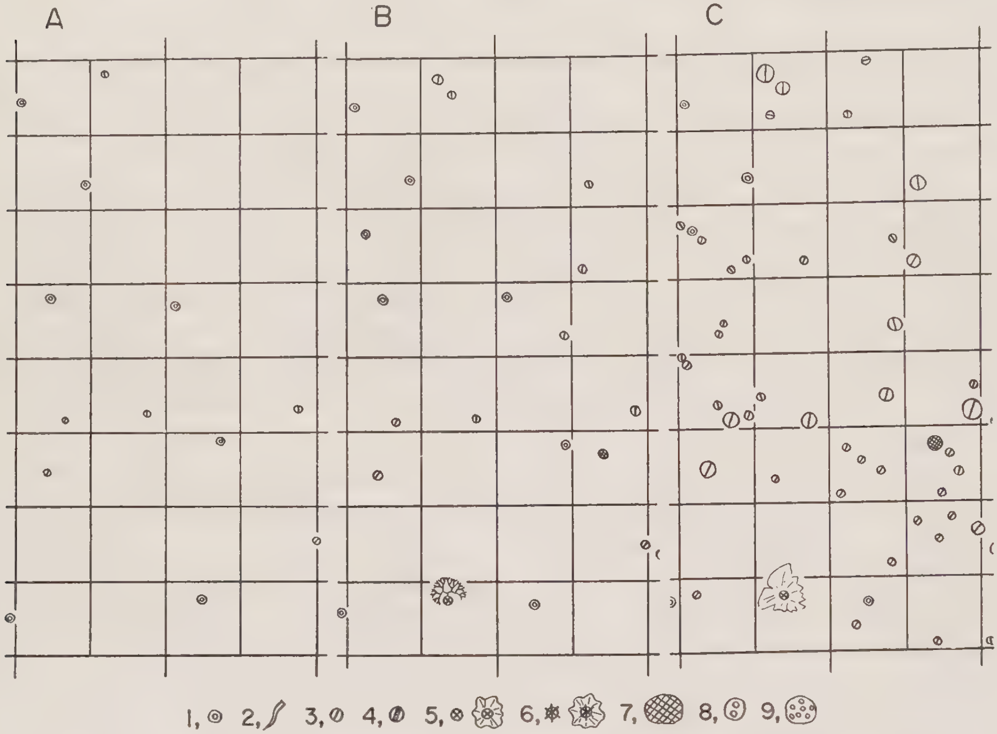

Fig. 2. Diagrammatic representation of a community commencing its development on January 31 in an area of 10 cm × 20 cm. A, 71st day (April 11); B, 82nd day (April 22); C, 92nd day (May 2). 1–9, markings of the species, numbers of which are shown in Table 2.

growth. Oldest *Balanus* had attained 7 mm in carinorostral diameter. The nudibranchs, one of the guests to the community of this stage, laid their egg clusters here and there over the surface (Fig. 2C; Pl. I, Fig. 3).

The fourth month. 101st day (May 11): Withering of the community originating in the decline of minute algae and hydroid colonies became more and more apparent. The surface was desolate of any vegetation or plant-like animals except *Bugula* and the community became flattened. Dwelling tubes of amphipods left attached everywhere on the surface were found gradually increasing. Animals attached anew were 82 individuals of *Balanus trigonus*, four of *Balanus tintinnabulum rosa* and one of *Spirorbis*. As the new immigrants 13 individuals of *Styela plicata*, one colony of *Leptoclinum mitsukurii* and a few *Hydroides norvegica* were numbered, though the last species was found on the marginal regions of the surface. In this stage, it was found that not only the attaching number is increased both in species and in individuals, but also the growth of the earlier dwellers has steadily progressed.

The largest barnacle grew as large as 8 mm in calibre and its shell was sufficient to provide the larvae of its own species with a substratum for attachment. With the growth of the constituents of the community, some benthic animals joined them

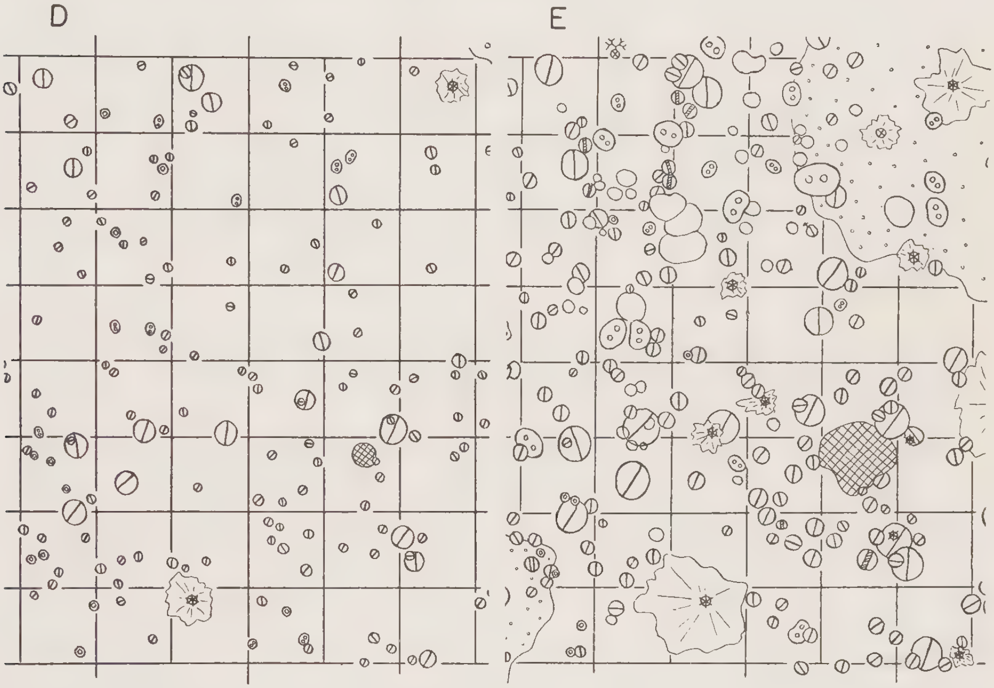

Fig. 3. Same in an area of 15 cm × 20 cm. D, 101st day (May 11); E, 121st day (May 31).

also. Those were several individuals of *Nereis japonica*, *Lineus sp.* about 50 mm long and so on (Fig. 3D; Pl. I, Fig. 4).

121st day (May 31): *Styela plicata*, *Balanus trigonus*, *B. tintinnabulum rosa* and *Bugula californica* multiplied further in their number. The areas covered by compound ascidians were enlarged, and several individuals of the brownish turbellarian, *Pseudoceros exoptatus*, were found creaping on them. Among the algae, *Ectocarpus* 30 mm long or more were growing here and there over the surface. The community became gradually larger in dimension by the rapid growth of *Styela plicata*, *Bugula neritina* and a Phaeophyta, *Colpomenia sinuosa* (Fig. 3E; Pl. II, Fig. 5).

The fifth month. 151st day (June 30): With their further growth and increase in their number *Styela plicata* and *Bugula neritina* grew fouled by many dwelling tubes of amphipods, abundant colonies of compound ascidians and so on. They were moreover covered with silt, exhibiting an appearance, so to speak, a jungle. Interior of this jungle is occupied by many animals that dislike a light, such as, *Ciona intestinalis*, sponges, and the benthos which had multiplied both in species and in number. The amount of fouling attained near its maximum (Pl. II, Fig. 6).

The sixth month and after. 191st day (August 9): *Bugula neritina* became extinct,

being destroyed by a high water temperature of summer (26°C or more) and the community jungle resumed a flattened state (Pl. II, Fig. 7). 245th day (October 2): As the corpse of dead *Bugula neritina* had been washed away, the original surface of the substratum was again exposed here and there, but still covered with *Styela plicata* for the greater part. *Spirorbis* and other small-sized animals having settled down earlier were dead under *Styela*, though *Balanus* and *Hydroides* were alive avoiding to lie beneath this by a conspicuous deformation (Pl. II, Fig. 8). After 245th day: By natural death, some of *Styela* began to fall down and original surface of the substratum became largely exposed. This recovery provided the larvae again with substratum suitable for attaching (KAWAHARA, 1960). The seqence of changes in the attachment and growth of fouling organisms was repeated anew on this wide exposed surface.

3. Attached species and changes in their number of individuals

Animals attached themselves on the test block during the period of examination by May 31 comprise 11 spp.: that is 2 hydrozoans, 2 polychaetes, 2 cirripeds, 3 bryozoans and 2 ascidians. Successive changes in the species and in the number of individuals or colonies are shown in Table 2. The species making their most frequent appearance are *Spirorbis foraminosus*, *Balanus trigonus*, *B. tintinnabulum rosa* and *Styela plicata*.

Spirorbis foraminosus made its first appearance on the 36th day (March 7) and was increased comparatively rapidly in number representing a dominant species during the course of earlier stage. *Balanus trigonus*, the occurrence of which was discernible as early as March 13 (the 42nd day), was extinguished within a short duration owing to a low temperature. About from the 76th day (April 6) onward, this species became dominant over *Spirorbis*. Its attachment to the block was again frequent from the 92nd day (May 2) onwards. Active attachment of this animal lasted until the 121st day (May 30) or somewhat later. *Balanus tintinnabulum rosa* settled down on the substratum step by step in increasing degree from the 92nd day (May 1) showing steady growth after that. *Styela plicata* beginning its attachment on the 98th day (May 8) showed an abrupt increase from that instant and its steady growth made it dominant next to *Balanus trigonus*. Change in the number of *Bugula neritina*, *Watersipora cucullata* and *Leptoclinum mitsukurii* was not then distinct, for these were at the beginning of their attaching season.

Although the first appearance of species and the sequence of changes in their number depend chiefly on the season in which the experiment was initiated besides on the locality, there are some changes in connection with the development. Diatoms, minute algae and hydroids decline as soon as they attain their prosperity. Other members multiply in their number little by little and in an early season their presence can not always be ascertained, but with the lapse of time increase of

Table 2.

Successive changes in the number of individuals or colonies in the community (from January 31 onward). Days A, lapse of days after the commencement of experiment; Days B, lapse of days after the previous examination. Upper column, number of attachment and number of extinction (–) occurring within an area of 20 cm × 20 cm; lower column, number of existing animals. +, ++, +++, (0–5 %), (5–15 %), (15–35 %): In hydroids and amphipods an imaginable maximum of quantity is taken as 100% ; in *Hydroides* the notation represents the attachment on the region circumscribing the central region.

Date	Mar. 7	Mar. 13	Mar. 22	Mar. 27	Apr. 1	Apr. 6	Apr. 11	Apr. 16	Apr. 22	Apr. 27	May 2	May 5	May 8	May 11	May 31	Total
Days A Days B	35	41 6	50 9	55 5	60 5	65 5	70 5	75 5	81 6	86 5	91 5	94 3	97 3	100 3	120 20	
POLYCHAETA																
1. *Spirorbis foraminosus*	4– 4	1–0 5	4–0 9	2–2 9	2–0 11	0–0 11	2–0 13	2–0 15	0–0 15	0–0 15	2–0 17		1–0 18			20–2 18
2. *Hydroides norvegica*													+– +	0–0 +	0–0 +	+
CIRRIPEDIA																
3. *Balanus trigonus*		1– 1	0–0 1	0–0 1	0–1 0	3–0 3	8–0 11	6–0 17	3–0 20	1–0 21	57–0 78	31–0 109	28–0 137	23–3 157	37–2 192	198–6 192
4. *Balanus tintinnabulum rosa*											3– 3		0–0 3	4–0 7	4–0 11	11–0 11
BRYOZOA																
5. *Bugula neritina*						1– 1	0–1 0	0–0 0	1–0 1	0–0 1	0–0 1		0–0 1	0–0 1	1–0 2	3–1 2
6. *Bugula californica*									1– 1	0–0 1	0-0 1		0–0 1	1–0 2	5 0 7	7–0 7
7. *Watersipora cucullata*										1– 1	0–0 1		0–0 1	0–0 1	0 0 1	1–0 1
ASCIDIACEA																
8. *Styela plicata*											0		7– 7	7–1 13	12–3 22	26–4 22
9. *Leptoclinum mitsukurii*											0		1– 1	0–0 1	1–0 2	2–0 2
HYDROZOA																
10. *Clytia delicatula*	+	+	+		+		++		+++		+			0		
11. *Obelia geniculata*					+		++		+++		+			0		
AMPHIPODA	+	+	+		++		++		+++		+++			+++		

species becomes more and more conspicuous. In *Spirorbis* the rate of increase comparatively high in an earlier stage descends in a later stage. About after the 121st day (May 31), the condition of the substratum is entirely altered from that of the initial stage (Fig. 3E; Pl. II, Fig, 5). The measurement same as that taken in earlier stage became no longer significant. This is the reason for which a precise measurement was ceased.

4. Successive changes in the population of *Balanus trigonus*

Growth and increase in number in *Balanus trigonus* can be regarded as to represent the successive change of the community, for this is the most dominant over other organisms during the chief course of the experiment.

In examining the growth extent, the carinorostral diameter was divided into classes by every 2 mm (except in the lowest class which was divided by every 1 mm) and the frequency in each class was computed with respect to every population examined (Table 3). Area covered by the base of each animal will be approximately estimated by a circle, the diameter of which is represented by the middle value of each class. On the basis of these values, histograms representing a sort of age composition were made with respect to every population. In Fig. 4 they are

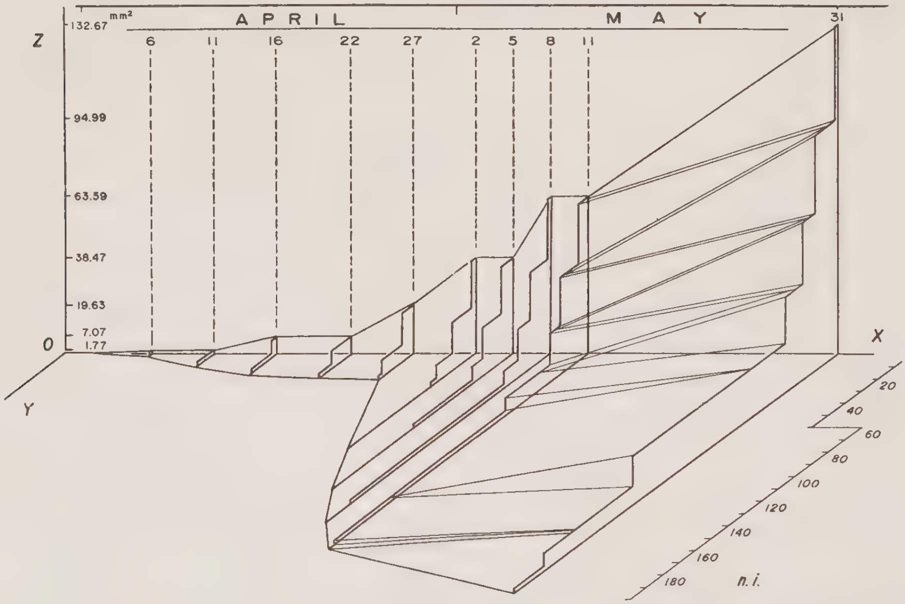

Fig. 4. Changes in the population of *Balanus trigonus*. x axis, time (in days): y axis, number of individuals; z axis, growth. *n. i.*, number of individuals (scale on y axis).

arranged to show the transition in accordance with the lapse of time. The figure indicates that *Balanus trigonus* begins to appear on the 66th day (April 6), but it does not make much increase until the 87th day (April 27), when its growth attains to

Table 3.

Changes in number and growth in the population of *Balanus trigonus*. Upper column, total of areas occupied by shells (mm^2); Lower column, frequency of individuals. A, class interval of carinorostral diameter (mm); B, middle value of the class; C, average of areas occupied by shells (mm^2), represented by the area of a circle, the diameter of which corresponds to the middle value of class; D, percentage of the total of areas occupied by shells to entire surface area; E, area got by dividing entire surface area by individual number (mm^2).

A	0–1	1–2	2–4	4–6	6–8	8–10	10–12	12–14	Sum of areas occupied by shells (mm^2)	D	Sum of individual numbers	E
B	0.5	1.5	3	5	7	9	11	13				
C	0.20	1.77	7.07	19.63	38.47	63.59	94.99	132.67				
Apr. 6	0.20 1	3.54 2							3.74	0.01	3	13332
Apr. 11	0.20 1	17.70 10							17.90	0.04	11	3636
Apr. 16	0.40 2	21.24 12	21.21 3						42.85	0.17	17	2352
Apr. 22	0	14.16 8	84.84 12						99.00	0.25	20	2000
Apr. 27	0	3.54 2	84.84 12	137.41 7					225.69	0.56	21	1904
May 2	10.20 51	5.31 3	70.70 10	215.93 11	115.41 3				417.55	1.04	78	512
May 5	9.80 49	61.95 35	42.42 6	215.93 11	307.76 8				637.86	1.59	109	368
May 8	3.20 16	164.61 93	56.56 8	157.04 8	384.70 10	127.18 2			893.29	2.23	137	292
May 11	0.84 4	182.31 103	190.89 27	137.41 7	384.70 10	381.54 6			1277.65	3.19	157	256
May 31	0	30.09 17	381.78 54	1786.33 91	423.17 11	445.13 7	1129.88 12	265.34 2	4461.72	11.15	194	208

a certain extent. It abruptly increases from the 92nd day (May 2) on and again the population becomes chiefly composed of small-sized individuals. Great increase lasts until the 101st day (May 11), when its rate is reduced. As a consequence the population on the 121st day (May 31) is constituted by comparatively large-sized individuals.

The area covered by the individuals belonging to each class of magnitude is represented by multiplying the average areas of the shell bases by the frequencies.

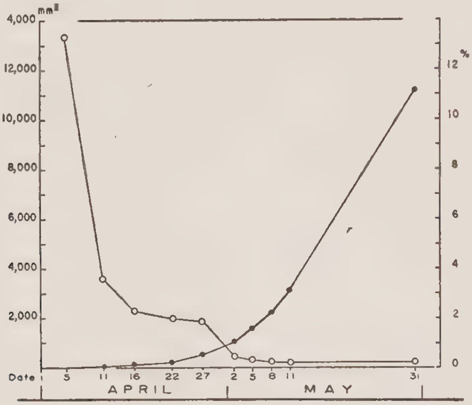

Fig. 5. Relation between the increase of the individual number and the growth in *Balanus trigonus* during the development of population. ○, area got by dividing entire surface area of substratum by individual number (mm^2); ●, percentage of sum of areas of shell bases to entire surface area of substratum (%).

The proportion between the sum of the products thus gained with respect to all classes and the entire surface area of the test block may give the growth index of the animals found within a certain definite area. The quotient got by the division of entire surface area by individual number gives population index which may represent the magnitude of population covering any restricted area.

The population index (in number) rapidly decreases in its value in earlier stages concomitant with the increase of individual number, but the reduction in the value soon becomes gradual. On the contrary, the growth index (in growth), the value of which is small in earlier stages, increases more and more with the lapse of time (Fig. 5). Such an inverse relation of the two indices is well illustrated by Fig. 4, in which the change in the value referring to y axis (number) is more distinct in earlier stages of the development of a population, whereas the same referring to z axis (growth) becomes more conspicuous as the time elapses. The transition in the nature of the developing population was recognizable by the 98th (May 8) in the present case (Fig. 5).

5. Consideration

a. "Meso-fouling" and its effect of promoting the fouling.

It is well known that the ordinary macroscopic fouling is preceded by the so-called mirco-fouling caused by bacteria, diatoms and other microfauna and flora. Of these, bacteria and protozoans will be excluded out of consideration, since these are too tiny to be dealt with here. Diatoms, such as, *Navicula spp.*, *Melosila sp.* and *Lichmophora sp.* were common, and *Ectocarpus spp.* and *Cladophora spp.* appeared to constitute the main components of minute algae, though exact identification was lacking with respect to these. The fouling caused by them lies in the rank between the micro- and macro-fouling with referrence to their volume and the velocity of their development. For convenience' sake this type of fouling will be distinguished by the provisional name of "meso-fouling". This fouling after its declination serves as a substratum suitable for other organisms. SCHEER (1945) states that well-developed algal community, composed mainly of diatoms and, in some seasons, of hydroids, has an effect to promote the settlement of bryozoans and other sessile animals. His conclution is largely in accordance with the result of the present study.

Effect of promoting the attachment of fauna and flora in the case of denuded surface has been observed by a number of authors (RICE, 1930; COE and ALLEN, 1937). It is presumed this merely results from the resolving of the poisonous substances from the artificial substrata into water. According to COE and ALLEN (1937), the effect is ascribable to that the surface becomes favorable by the retention of microscopic organisms and minute particles from the previous growth. KNIGHT-JONES and CRISP (1953) concludes that ship-bottoms cleand from fouling by a mere scrubbing down are brought into a rapid re-colonization as a result of "gregariousness" (KNIGHT-JONES and STEVENSON, 1950) in the nature of sessile animals. The effect of extinct "meso-fouling" upon the macro-fouling may find its nearest parallel to these except for the case of "gregariousness".

b. Development of community and replacement of species.

As emphasized by SCHEER (1945), it is essential in the study of a developing community to distinguish the true succession from the seasonal succession. In littoral community the presence of true succession is usually considered doubtful (SHELFORD, 1930; MCDOUGALL, 1943; SCHEER, 1945; Woods Hole Oceanogr. Inst., 1952). Nevertheless, the fouling community shows a certain replacement of species, a fact which is liable to be confused with a true succession.

It has repeatedly been noticed that a bacterial film, a micro-fouling, has an effect of promoting the attachment of larger forms (MILLER, RAPEAN and WHEDON, 1948; CRISP and RYLAND, 1959). The "meso-fouling" has a similar effect after the decline. Moreover, micro-, "meso-" and macro-foulings attain their height in due order, and each of the precedings are destructed by the flourishing of the succeeding. This may belong to a kind of succession, though not in the strict sense of the word.

In the fouling community there is a replacement of a species with another, the

autogenic succession, resulted from so-called biotic reaction (Clements and Shelford, 1939). For example, *Spirorbis foraminosus* prentifully appearing in an earlier stage of the development of community as a pioneer species is strongly reduced in number in a later stage. On the contrary, larger benthos make their appearance only in the later stages, in which the community is rich in their foods and shelter.

c. Stages in the development of community.

Entire course of development of a fouling community is divisible into a number of stages. The days requisite to attain each stage are not universally applicable, but inherent to the present experiment.

Stage I: The surface remaining clean from any stain to the naked eye (21st day, February 20) becomes yellowish green on account of the attachment and growth of diatoms and other minute algae (31st day, March 2).

Stage II: Pioneer species, *Spirorbis foraminosus*, begins to settle down (36th day, March 7) and other species follow little by little (82nd day, April 22). This stage represents the one in which the principal species settle down.

Stage III: Fauna and flora make their growth attaining a considerable enlargement in their size (92nd day, May 2). Although new colonization is still taking place, change of community consists principally in the multiplication of the volume, which lasts until the 121st day (May 31). The stage is characterized by the steady growth of the dominant animal.

Stage IV: Dominant species reaching the height of their growth, the community accomplishes prodigious development (151st day, June 30, or later). This is the stage in which the organisms are in full flourish.

Stage V: "Standing crops" abruptly decrease in their volume because of the extinction of the dominant species due to natural death (191st day, August 9). The stage is characterized by the decline of community.

Stage VI: Principal fouling animals become extinct, giving rise a disappearance of the greater part of community, and the original substratum is again exposed to a large extent.

Despite our ample knowledge on the seasonal changes of a fouling community, little has been known about its developmental cycle. Scheer (1945), in his study on the developmental course of community, lays much stress upon the alternation sequence of species. The present study directs special attention to the role of growth and span of life of the constituent species which they play during the course of change in community, and views the subject from a new angle.

d. Diagrammatic representation of the development of a community.

Schematic representation of an ecological phenomenon has frequently been made with success, as, for example, we can find this in Crisp's (1959) work on the dissemination of a marine animal. Development of a fouling community may easily be grasped by the aid of a similar graphic representation (Kawahara, 1960).

When we take time (in days), number of individuals (or colonies) and extent of growth on x, y and z axes in the solid co-ordinates respectively, we can represent the cumulative curve of the number of attached individuals by $y=f(x)$ and their growth curves by $z=f'(x)$ (Fig. 6). Growth curve starting from every point on $y=f(x)$ will make in all a curved surface which encloses together with xy and xz planes a solid. A section of this solid at a definite time indicates the quantity of population by its area and "age composition" by its shape.

As may be seen from the figure inserted, in earlier stages, during which a large number of individuals are attached to the substratum, but arrested in their growth, the shape of the section is prolonged parallel with y axis, and not very tall (Section I, Stage II, attaching period). As the organisms make their growth the sectioned surface becomes taller in relation to z axis and grows larger in area (Sections II and III, Stage III, growth period). When the majority of the organisms draw nearer to their full growth, the section becomes more or less rectangular in shape (Sections V and VI, Stage IV). After that, older individuals meet their end and the section begins to be reduced in area, the dead individuals being represent-

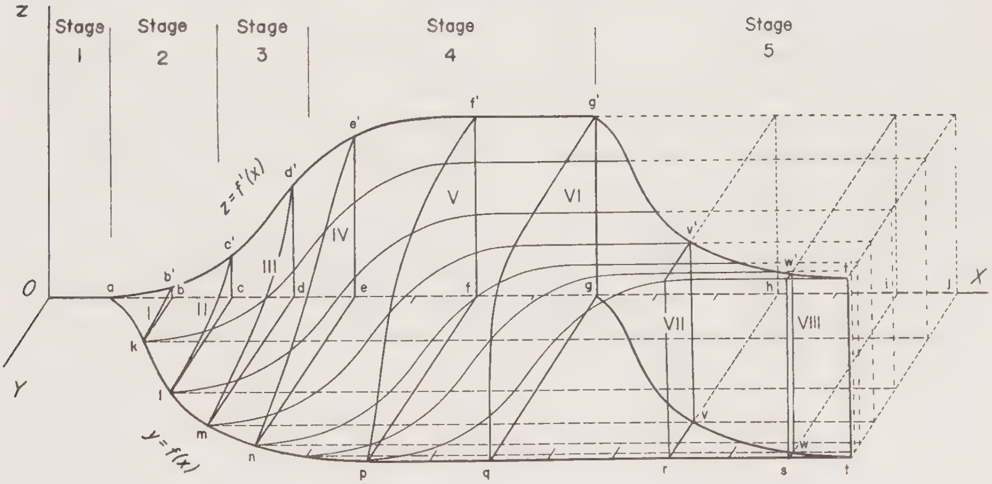

Fig. 6. "Analytical graph" representing the developing population or community. x axis, time; y axis, number of individuals; z axis, growth. $y=f(x)$, cumulative curve in the number of individuals; $z=f'(x)$, their growth curves. $a, b, \cdots j$, time on x axis; ag, mv, pt, natural duration of life; $gvwt$, curve showing the extinction of organism. $I, II, \cdots VIII$, sections indicating the state of population or community at the instants $b, c, \cdots i$.

ed by a quadrate enclosed by dotted lines in sections VII and VIII. The extreme of this reduction means the complete disappearance of the population at the point t. The process of the reduction corresponds to Stages V and VI. The sequence of events is exactly in accord with a series of histograms founded on the actual data of the population changes in *Balanus trigonus* (Fig. 4).

e. Genesis of fouling community.

It is evident from the diagrammatic representation inserted above that a community at a definite time, which is illustrated by a section of the solid in the diagram, is a result of the preceding development. Its genesis indicates that counting the number during the Stage II is indispensable for understanding the state of the community at the stages III and IV.

Summary

1) Observation on the development of a fouling community growing on a concrete test block immersed in the sea at Tomioka, Amakusa, Kumamoto Prefecture on January 31, 1946 was made for 250 days ranging from February to October.

2) Owing to a low temperature of colder season, the surface of the substratum was clean to the naked eye for about first 30 days. A "meso-fouling" caused by diatoms and other minute algae precedes the ordinary macro-fouling. Hydroids and tube-dwelling amphipods then follow. *Spirorbis* made their appearance in a comparatively early stage of community, showing a decreasing tendency in advanced stages.

3) The community grew gradually complicated during the spawning season of attaching animals, showing the following series of stage: i. Stain of substratum as a result of "meso-fouling". ii. Increase in the number (attaching period). iii. Growth of individuals (growth period). iv. Increase in full grown individuals. v. Decline of dominant species.

4) On account of the extinction of the dominant species, original surface was again exposed, thus providing a new colonization with a suitable substratum.

5) The genesis of the community indicates that counting the number of individuals during the "attaching period" is indispensable for understanding the state of community in later stages.

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Explanation of Plate I

Changes in a fouling community from January 31, 1946 onward. (× 3/8).

Fig. 1. Heavy fouling by diatoms and minute algae, covered with silt. (71st day, April 11).

Fig. 2. Height of "meso-fouling". Notice hydroids growing over the surface. (82nd day, April 22).

Fig. 3. Beginning of decline of "meso-fouling". Notice nudibranchs and their scattering egg clusters. (92nd day, May 2).

Fig. 4. Flattened surface lacking in any drifting things, leaving a large number of amphipod tubes. Extinction of "meso-fouling" and growth of barnacles. (101st day, May 11).

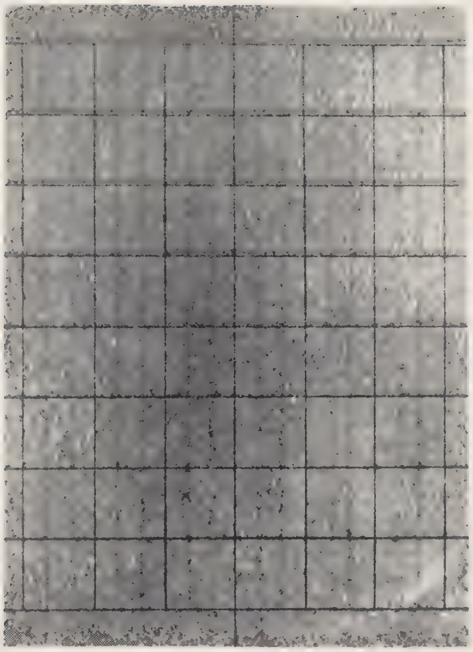

Fig. 1.

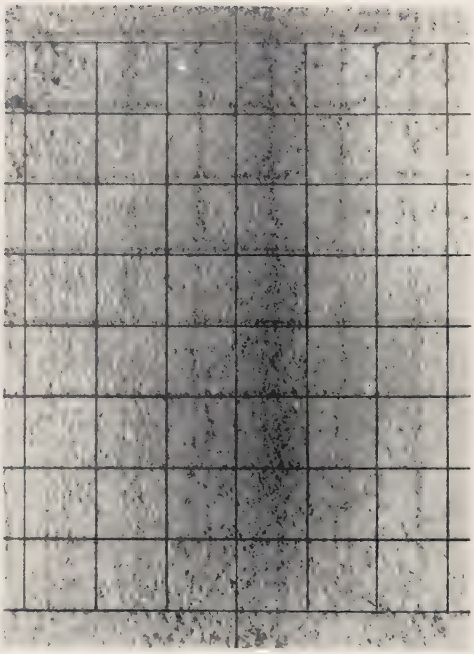

Fig. 2.

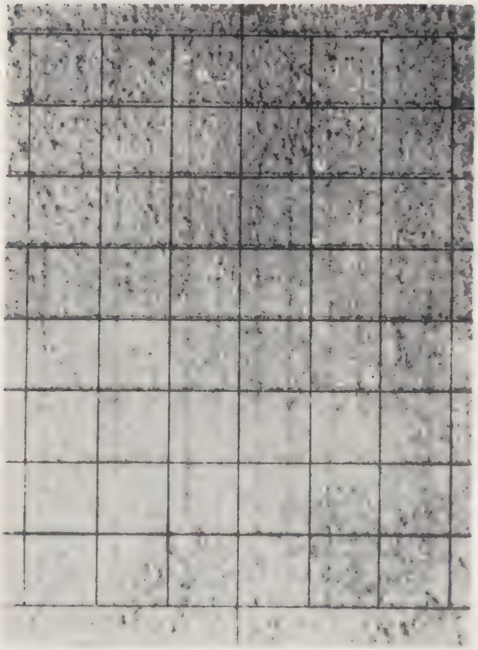

Fig. 3.

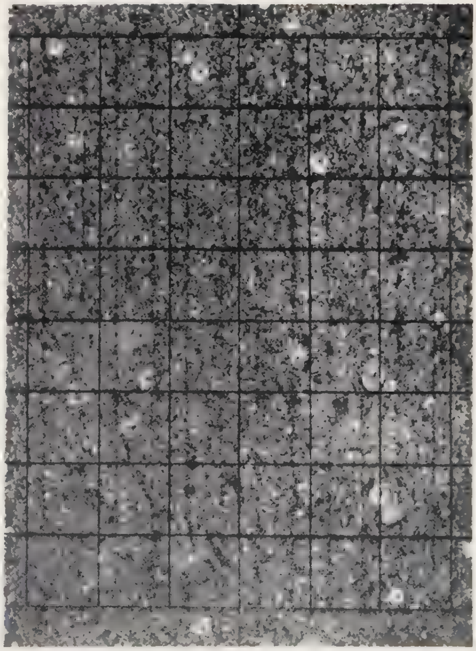

Fig. 4.

Explanation of Plate II

Same.

Fig. 5. Community rich in growing organisms. Beginning of bulky fouling with larger benthos. (121st day, May 31).

Fig. 6. Jungle like community. Notice *Bugula neritina* and *Styela plicata* both in flourish. (151st day, June 30).

Fig. 7. Declination of *Bugula neritina*. Notice the community without any drifting part. (191st day, August 9).

Fig. 8. Extinct *Bugula neritina* and flourishing *Styela plicata*. Notice exposed surface. (245th day, October 2).

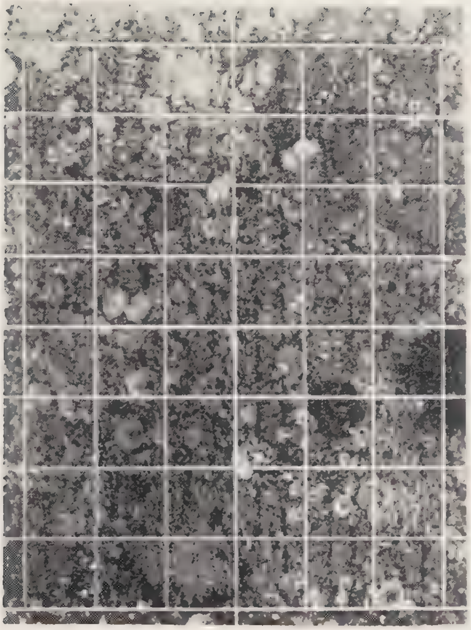

Fig. 5.

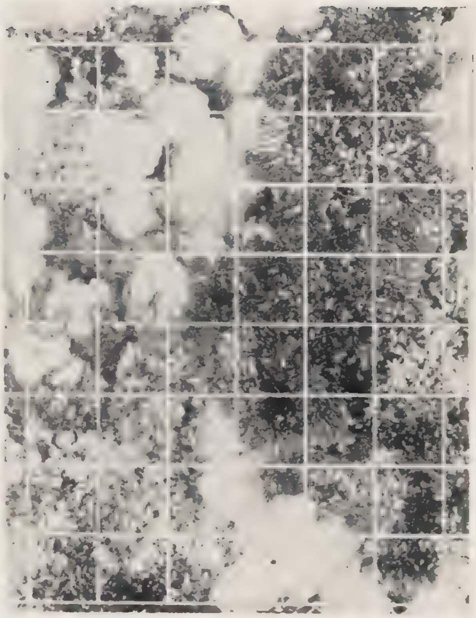

Fig. 6.

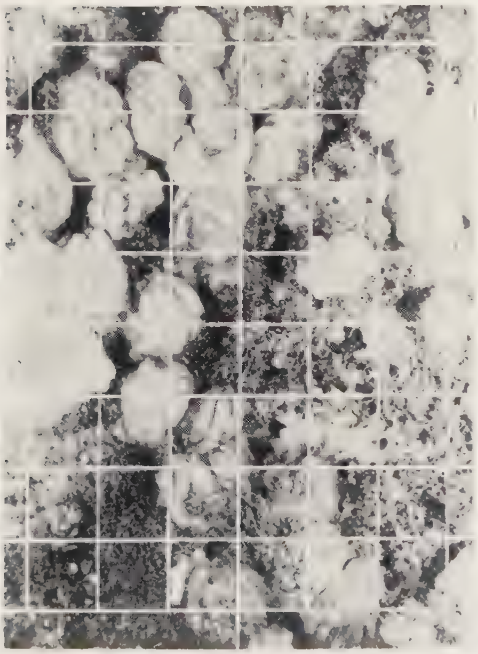

Fig. 7.

Fig. 8.

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Vol. 4, No. 2, December 15, 1962

Anatomical and Taxonomical Studies on the Carangid Fishes of Japan

By

Kiyoshi Suzuki

I. Introduction

The Carangidae is a large family belonging to the order Percida, and comprises many species which are widely distributed throughout tropical and warm seas of the world and for the most part valuable as food. In the middle and southern part of Japanese waters, which fall on the northern boundary of the distribution of this family, a large number of the species are caught in a large quantity by fixed shore net and other fishing implements.

There are several works dealing with the classification of the Carangidae. Wakiya (1924), making a thorough revision of the family distributing in the seas adjacent to Japan, including Bonin Islands, Ryukyu Islands and Formosa, recorded 76 species which he assigned to 4 subfamilies and to 14 genera. Oshima (1925) made a taxonomic study with respect to the forms found in the surrounding waters of Formosa, and reported the occurrence of 38 species which are referable to 16 genera. For these thirty years, their works have been the accepted standard of the classification of the Japanese carangid fishes. There remain, however, some doubtful points in the systematics of the ranks higher than genera, in the interrelationships among the families and in their phylogeny, since those studies were undertaken mainly based upon the external features.

Our knowledge on the osteology of this group is rather meager and unsatisfactory. Starks (1911), in his osteological studies of the family, deduced the probable affinity of the family to the Scombridae from the comparison of 21 representative species with respect to their crania, suspensoria and opercular apparatus, orbital bones, hyoid apparatus, branchial apparatus, shoulder girdles, pelvic girdles and vertebral columns. He attempted later (1926) a comparative study on the ethmoid region of the cranium in 16 carangid species. Inserting fine illustrations of the skulls of *Seriola zonata*, *Scomberoides tolooparah*, *Vomer setipinnis* and *Selene vomer* in his excellent work, Gregory (1933) devoted a discussion for some respects to the phylogeny of the Carangidae. In addition to them, Hollister (1937), Merriman (1943) and Hotta (1958) added each valuable contributions to the osteology of the fami-

ly. Their works, however, are not so perfect as to clarify the general bony characters of the family exhaustively, since they treated no more than rather restricted species.

The present report aims the comparative study of 39 carangid species found around Japan particularly with respect to their crania, suspensoria and opercular apparatus, jaw bones, orbital bones, hyoid apparatus, gill arches, shoulder girdles, pelvic girdles, vertebral columns and scutes in order to disclose the systematic and phylogenetic significances of the interspecific differences in these bones. Reviewing the ranks higher than the genera, it intends, further, to establish a system more rational than the preexisting one, and to find the interrelationships among the genera and subfamilies. Diagnoses of the species are given anew on the basis of the internal anatomy.

1. Material

A great amount of materials on which the present study is based were mostly taken by means of fixed shore nets, or deep-sea trawlers, from the following localities: Yaizu and Shimoda, Shizuoka Prefecture; Izu-Ôshima; Shineshima; Hachijoshima; Miya, Aichi Prefecture; Tsu, Toba, Owase, Shimakatsu, Kuki and Nikishima, Mie Prefecture; Yôrô, Kyoto Prefecture; Shimonoseki, Yamaguchi Prefecture; Nagasaki, Nagasaki Prefecture; Amakusa-shima; Amami-Ôshima; Palau Islands; Formosa; South China sea. The materials are for the greater part deposited in the Faculty of Fisheries, Prefectural University of Mie. The specimens taken from the South China sea are kept in the Department of Fisheries, Faculty of Agriculture, Kyoto University, and those from Amami-Ôshima in Misaki Marine Biological Laboratory attached to Kyoto University. The author was enabled to examine them by courtesy of Dr. Kiyomatsu Matsubara. He was also made possible through the kindness of Dr. Tokiharu Abe to study the specimens procured at Palau Islands and preserved in the Department of Zoology, Faculty of Science, Tokyo University.

The following is the list of species, which are arranged in conformity with the new scheme to be proposed by the author.

Subfamily Chorineminae
- Genus *Chorinemus*
  - *Chorinemus orientalis* Temminck and Schlegel

Subfamily Trachinotinae
- Genus *Trachinotus*
  - *Trachinotus bailloni* (Lacépède)
  - *Trachinotus ovatus* (Linné)

Subfamily Naucratinae
- Genus *Seriola*
  - *Seriola quinqueradiata* Temminck and Schlegel

Seriola purpurascens Temminck and Schlegel

Genus *Naucrates*

Naucrates ductor (Linné)

Genus *Elagatis*

Elagatis bipinnulata (Quoy and Gaimard)

Subfamily Caranginae

Genus *Caranx*

Caranx sexfasciatus Quoy and Gaimard
Caranx xanthopygus Cuvier and Valenciennes
Caranx hippos (Linné)
Caranx melampygus Cuvier and Valenciennes
Caranx bixanthopterus Rüppell
Caranx ishikawai Wakiya

Genus *Citula*

Citula armatus (Forskål)
Citula plumbeus Quoy and Gaimard
Citula dinema (Bleeker)
Citula malabaricus (Bloch and Schneider)

Genus *Atropus*

Atropus atropus (Bloch and Schneider)

Genus *Uraspis*

Uraspis helvolus (Forster)

Genus *Gnathanodon*

Gnathanodon speciosus (Forskål)

Genus *Alectis*

Alectis ciliaris (Bloch)
Alectis major (Cuvier and Valenciennes)

Genus *Carangoides*

Carangoides jordani Nichols
Carangoides hemigymnostethus (Bleeker)

Genus *Kaiwarinus*, new genus

Kaiwarinus equula (Temminck and Schlegel)

Genus *longirostrum*

Longirostrum delicatissimus (Döderlein)

Genus *Selaroides*

Selaroides leptolepis (Cuvier and Valenciennes)

Genus *Atule*

Atule djeddaba (Forskål)
Atule affinis Rüppell

Atule miyakamii Wakiya

Genus *Trachurops*

Trachurops crumenophthalmus (Bloch)

Genus *Decapterus*

Decapterus reussellii (Rüppell)

Decapterus macrosoma Bleeker

Decapterus muroadsi (Temminck and Schlegel)

Decapterus lajang Bleeker

Decapterus maruadsi (Temminck and Schlegel)

Decapterus akaadsi Abe

Genus *Trachurus*

Trachurus japonicus (Temminck and Schlegel)

Subfamily Megalaspinae, new subfamily

Genus *Megalaspis*

Megalaspis cordyla (Linné)

2. Acknowledgement

The author wishes to express his sincere gratitude to Dr. Yaichiro Okada for the kind guidance which the professor gave the author during a long period. His grateful acknowledgement is made to Dr. Kiyomatsu Matsubara, Professor of Kyoto University, and to Prof. Sueo M. Shiino, Dean of the Faculty of Fisheries, the Prefectural University of Mie, both of whom helped him in every possible way throughout the entire course of the study, besides in reading over and correcting the manuscript. His heartfelt thanks are also due to Prof. Ichiro Tomiyama, Dr. Tokiharu Abe, Prof. Reizo Ishiyama, Dr. Akira Ochiai, Dr. Hirotoshi Asano, Dr. Kozo Saishu and Dr. Saburoh Kubota all of whom gave him assistance in various ways.

II. Anatomy

Under this reading, comparative studies are made with special reference to ten bony parts: the cranium, the jaw bones, the suspensorium and opercular apparatus, the hyoid apparatus, the gill arch, the orbital bones, the shoulder girdle, the pelvic girdle, the scutes and the vertebral column. The studies appear to have made a certain success in providing us with the grounds for ranking 39 Japanese carangid fishes into genera or subfamilies and for the speculation on the way of their differentiation. Phylogenetic significances which those bony parts may have are also disclosed at the end of this section.

Specimens dealt with in this study have been preserved in 10 per cent aqueous solution of formalin. The localities in which they were collected and their body sizes are listed in Table 1.

Table 1.
Locality and body size of specimens used for anatomical examination.

Species	No.	S. L.	Locality
Chorinemus orientalis	1	177.0	Owase
Trachinotus bailloni	1	144.0	Toba
Seriola quinqueradiata	1	430.0	Kuki-ura
Seriola purpurascens	1	273.0	Kuki-ura
Naucrates ductor	1	267.0	Shimakatsu
Elagatis bipinnulata	1	405.0	Nikishima
Megalaspis cordyla	1	246.0	Kumano-nada
Caranx sexfasciatus	1	135.0	Owase
Caranx xanthopygus	1	178.0	Kuki-ura
Caranx melampygus	1	216.5	Amami-Ôshima
Caranx bixanthopterus	1	180.5	Amami-Ôshima
Caranx hippos	1	254.0	Shimonoseki
Caranx ishikawai	1	377.0	Kuki-ura
Citula plumbeus	1	200.5	Kuki-ura
Citula dinema	1	220.0	Owase
Citula malabaricus	1	196.0	Owase
Atropus atropus	1	178.0	Kuki-ura
Uraspis helvolus	2	280.0—204.0	Kuki-ura
Gnathanodon speciosus	1	202.0	Palau
Alectis ciliaris	1	339.0	Owase
Alectis major	1	154.0	Shimonoseki
Carangoides jordani	1	245.0	Yôrô
Carangoides hemigymnostethus	1	215.0	Izu-Ôshima
Kaiwarinus equula	2	174.0— 68.0	Owase
Longirostrum delicatissimus	1	227.0	Owase
Selaroides leptolepis	1	124.0	Kumano-nada
Atule djeddaba	1	210.0	South China Sea
Atule affinis	1	184.0	Tsu
Trachurops crumenophthalmus	2	190.5—183.0	Kuki-ura
Decapterus russellii	1	306.0	Owase
Decapterus macrosoma	2	284.0—241.0	Izu-Ôshima
Decapterus muroadsi	2	289.0—275.0	Owase
Decapterus lajang	1	243.0	Shimoda
Decapterus maruadsi	2	279.0—203.0	Kuki-ura
Decapterus akaadsi	1	175.0	Owase
Trachurus japonicus	4	250.0—153.0	Owase

No., Number of specimens
S. L., Standard length (in mm)

1. Cranium

Starks (1911 and 1926), Gregory (1933), Merriman (1943) and Hotta (1958)

have made valuable contributions to our knowledge on the crania of the carangid fishes.

In his comparative study of various species, STARKS (1911) insists the presence of probable relationships between the Carangidae and the Scombridae, pointing out their mutual resemblance in the important cranial features. He makes, in another work (1926), the characters of the ethmoid region of the cranium clear with reference to 16 carangid species. In his extensive and valuable studies on fish skulls, GREGORY (1933) gives full illustrations on those of several species, and throws light on the phylogeny of the family. Founded on the stained and cleared specimens, MERRIMAN (1943) gives a brief description on the cranium of *Trachurus lathami* NICHOLS. HOTTA (1958) reports an abnormality in the development of cranial bones in *Trachurus japonicus* TEMMINCK and SCHLEGEL.

Although the constitution of the cranial elements and their arrangement are largely uniform throughout all the species examined by the author, some noteworthy differences can be observed in the configuration of some of them as well as in the same of the cranium as a whole. Disclosure of the interspecific differences naturally necessitates qualitative as well as quantitative examinations. The measurements herein taken are as follows: (1) Cranial length is measured from the tip of vomer to the end of basioccipital. (2) Rostral length is taken from the tip of vomer as far back as the line combining the lateral extremities of ectethmoids of the two sides. (3) Diameter of orbit is represented by the distance between the lateral end of the ectethmoid and the antero-lateral angle of the sphenotic. (4) Postorbital length is meant by the distance from the latter angle to the posterior end of basioccipital. (5) Depth implies the vertical length passing through the middle of the supraoccipital crest. (6) Width means the widest calibre across the two sphenotics. (7) Interorbital width corresponds to the calibre in the narrowest part of the two frontals above the orbit.

Preorbital region of cranium:

The vomer is an unpaired bone situating on the foremost region of the cranium. It is triangular or quadrangular in form and bears on its dorsal surface a medio-longitudinal keel, the so-called mesethmoid-vomerine keel. Development of the keel varies in its extent according to the species. In *Trachurops crumenophthalmus*, *Selaroides leptolepis* and *Gnathanodon speciosus* the conspicuously elevated keel assumes the appearance of a thin plate (Fig. 5, A•B; Fig. 7). But in others, development of the plate is feeble, or moderate. On the ventral surface the vomer is usually divided into two parts, the head portion and the median shaft. In most of the species the median shaft is somewhat convex along the midline. In the species, such as, *Decapterus muroadsi*, *Longirostrum delicatissimus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus* and *C. ishikawai*, a shallow, longitudinal groove runs along the midline of the shaft. The dentition of the vomer varies in accordance with the species. In *Decapterus macrosoma*, *D. muroadsi*, *Longirostrum delicatissimus*,

Atule djeddaba, *Gnathanodon speciosus*, *Selaroides leptolepis* and *Alectis ciliaris* the dentition is entirely absent. In the rest species the teeth are well-developed on the ventral sur-

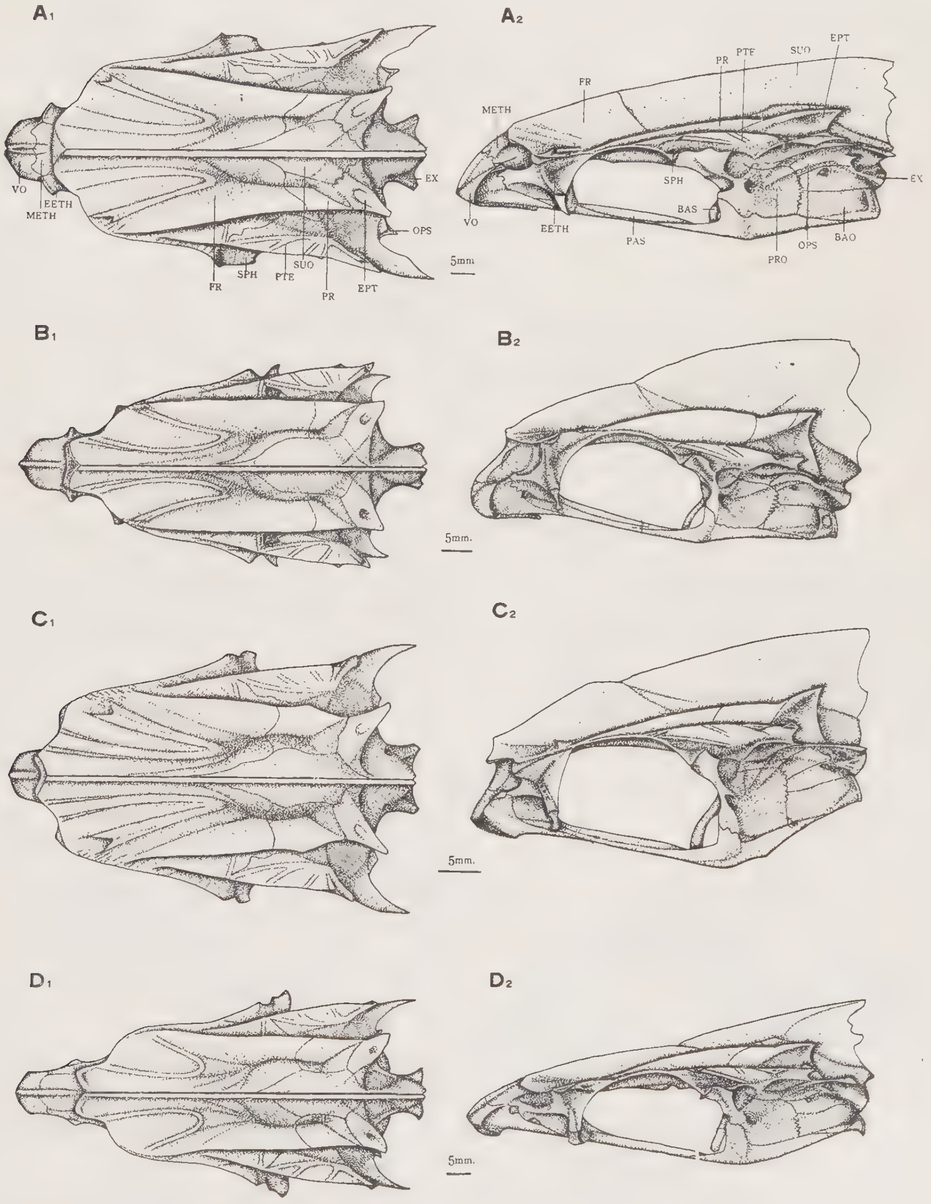

Fig. 1. Upper and lateral aspects of the cranium in 4 species. A, upper aspect of the cranium: A, lateral aspect of the same. BAO, basioccipital; BAS, basisphenoid; EETH, ectethmoid; EPT, epiotic; EX, exoccipital; FR, frontal; METH, mesethmoid; OPS, opisthotic; PAS, parasphenoid; PR, parietal; PRO, prootic; PTE, pterotic; SPH, Sphenotic; SUO, Supraoccipital VO, vomer. A, *Seriola quinqueradiata*; B, *S. purpurascens*; C, *Naucrates ductor*; D, *Elagatis bipinnulata*.

face of the vomer without exception, though varieties are found in their arrangement. In *Kaiwarinus equula*, *Seriola quinqueradiata*, *S. purpurascens* and *Elagatis bipinnulata* the teeth are grown in a cuneiformed longitudinal area, which extends from the fore end of the head to the middle of the median shaft. They are either villiform or granuliform, and are crowded together. In *Carangoides jordani*, *Atule affinis* and *Alectis major* they form a transverse, crescentic band, encircling the anterior part of the head. *Decapterus lajang*, *D. maruadsi* and *Trachurops crumenophthalmus* are peculiar in having the teeth arranged on a small ovoidal band on each side of the head. *Trachurus japonicus* has the uniserial teeth along the anterior margin of the head. In the rest of species the teeth form a rhomboidal or triangular band. In addition to such a band, a conspicuous longitudinal crest armed with the villiform teeth on its ventral edge is present along the midline of the median shaft in *Trachurus japonicus*, *Decapterus russellii*, *D. lajang*, *D. maruadsi* and *D. akaadsi* (Fig. 6, A•D•E). The vomer is articulated postero-dorsally to the mesethmoid as well as to the ectethmoid, and ventrally to the parasphenoid.

The mesethmoid is unpaired and is inserted between the ectethmoids of both sides. It adjoins along its anterior edge to the vomer, and gives off posteriorly a process which is inserted between the two frontals and separates these for a short distance. It has a slight longitudinal ridge on the dorsal surface along the midline and forms together with the elevations of vomer the mesethmoid-vomerine keel in most of the species. In *Megalaspis cordyla*, *Atule djeddaba*, *Trachinotus bailloni*, *Seriola quinqueradiata*, *S. purpurascens*, *Elagatis bipinnulata* and *Chorinemus orientalis* the medio-dorsal ridge is blunt on its free margin, whilst in others it is somewhat acuter. *Alectis major*, however, forms an exception in that the dorsal surface of the mesethmoid is somewhat depressed and entirely deprived of median elevation. The superior portion of the mesethmoid varies in its shape according to the species. In *Trachurops crumenophthalmus*, *Carangoides jordani*, *C. hemigymnostethus*, *Longirostrum delicatissimus*, *Uraspis helvolus*, *Selaroides leptolepis* and *Gnathanodon speciosus* the portion is anteriorly concave, scarcely protruding from the diverging fore ends of the frontals. The mesethmoid-vomerine keel which is distinct only in the lower portion near the vomer is replaced by a somewhat deep concavity in that portion (Fig. 4, A•B•D; Fig. 5, A•B; Fig. 7; Fig. 8). In *Megalaspis cordyla*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. melampygus*, *C. bixanthopterus*, *C. hippos*, *C. ishikawai*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagatis bipinnulata* and *Chorinemus orientalis* the superior portion is widened from side to side and is projecting anteriorly beyond the frontals (Fig. 1; Fig. 2; Fig. 9; Fig. 10). Especially, in *Caranx ishikawai* and *C. hippos* the anterior portion assumes a V-shape in dorsal view. In *Trachinotus bailloni* the superior portion is much projecting beyond the frontals in such a way as to give rise to a strong concavity in lateral view which in turn, looks like a crescent in dorsal view (Fig. 10). Such is also the case with *Atule djeddaba*, in which, however, the projection and concavity are less conspicuous (Fig. 5, D).

The ectethmoids are paired, lying on either side of the mesethmoid. Each of

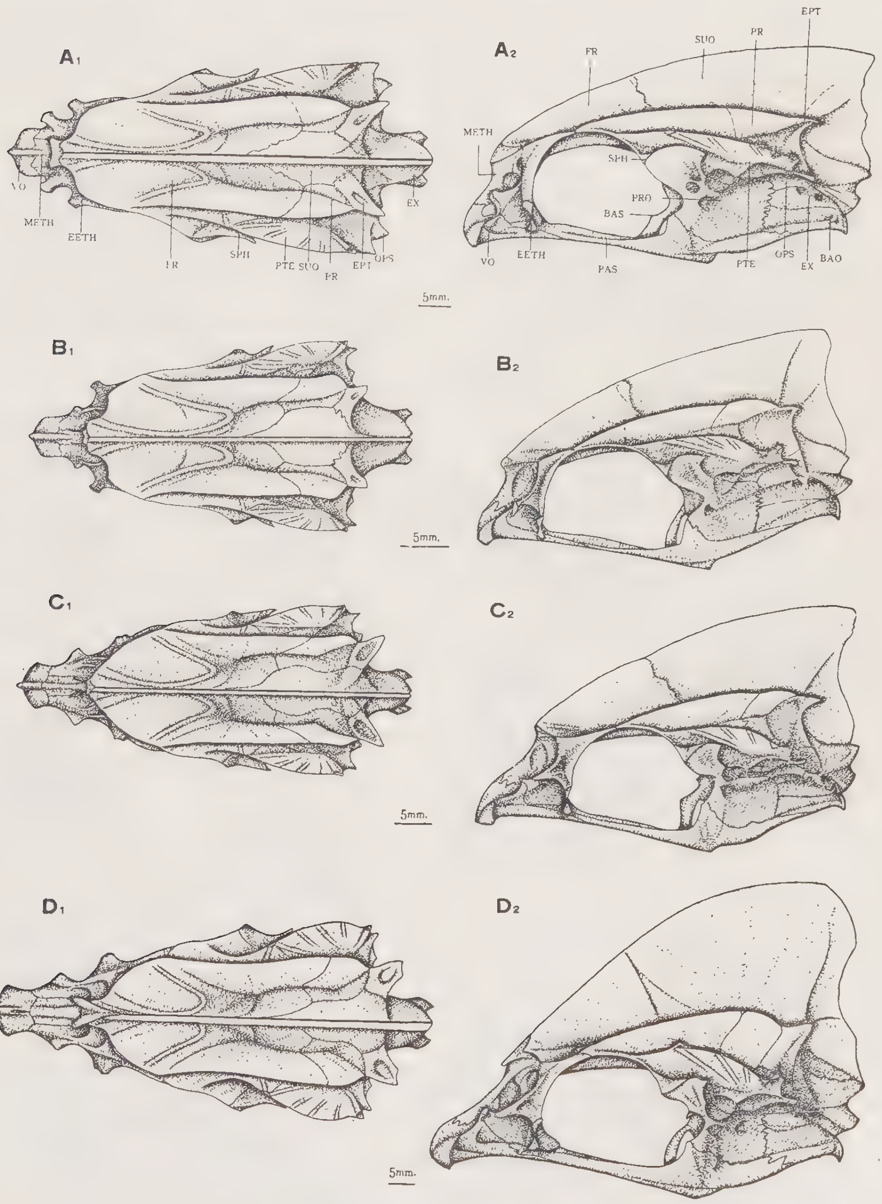

Fig. 2. Upper and lateral aspects of the cranium in 4 species. A, *Caranx hippos*; B; *C. xanthopygus*; C, *C. melampygus*; D, *C. ishikawai.*

them is articulated dorsally to the parasphenoid. Each forms on the side a somewhat massive swelling, which comes in contact with the palatine on the angulated lower edge. In *Alectis ciliaris* and *A. major*, however, the swelling is rounded in outline and continues gracefully upward to the frontal without forming an angle (Fig.

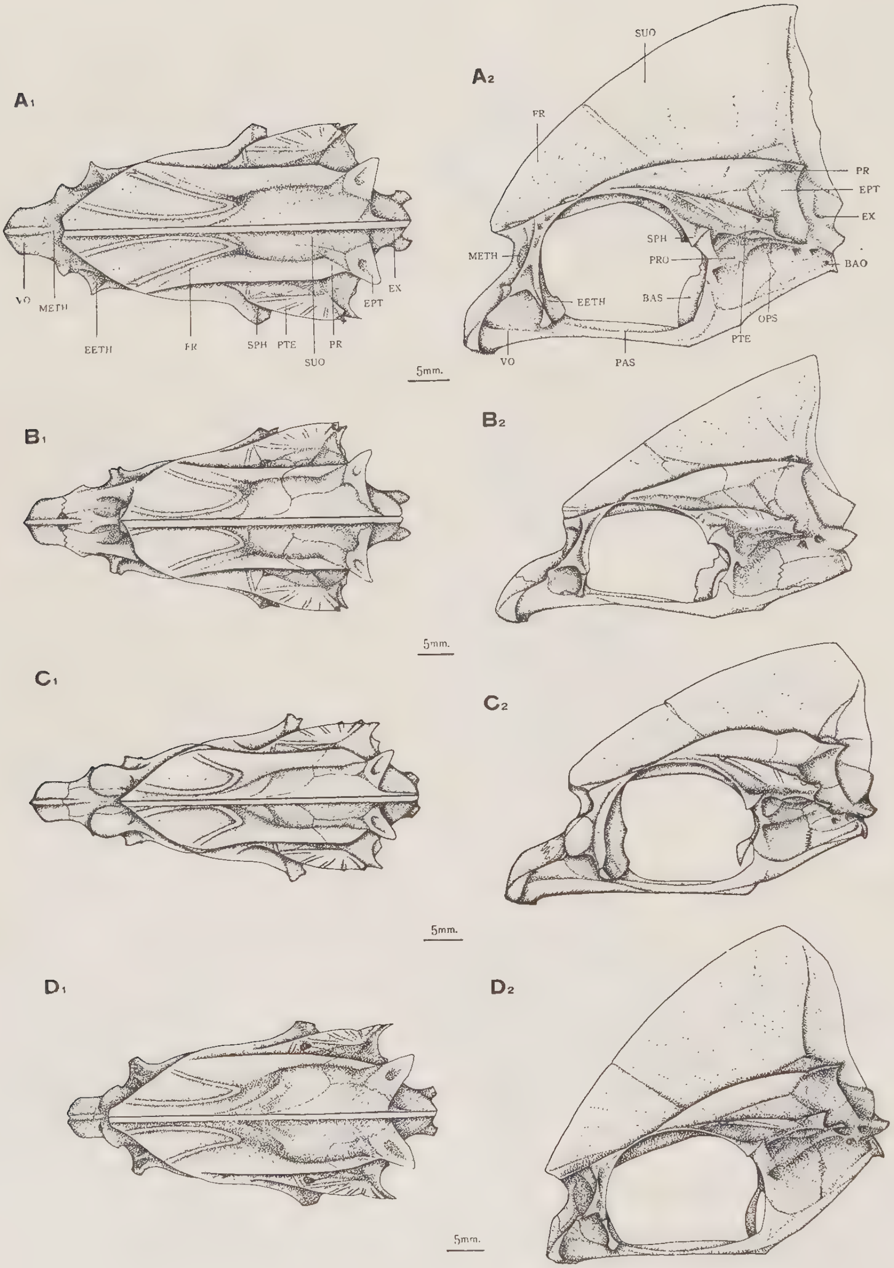

Fig. 3. Upper and lateral aspects of the cranium in 4 species. A, *Citula plumbeus*; B, *C. dinema*, C, *C. malabaricus*; D, *Atropus atropus*.

11). In many of the species the ectethmoid has a cavity on its dorsal surface. In ordinary cases the mesethmoid takes part in the formation of the wall of this cavity, which will be termed the olfactory cavity. Development of the cavity varies in

accordance with the species. In *Megalaspis cordyla*, *Atropus atropus*, *Uraspis helvolus*, *Seriola quinqueradiata*, *S. purpurascens*, *Trachinotus bailloni*, *Naucrates ductor* and *Chorinemus orientalis* it is scarcely developed (Fig. 1, A·B·C; Fig. 3, D; Fig. 9; Fig. 10; Fig. 12).

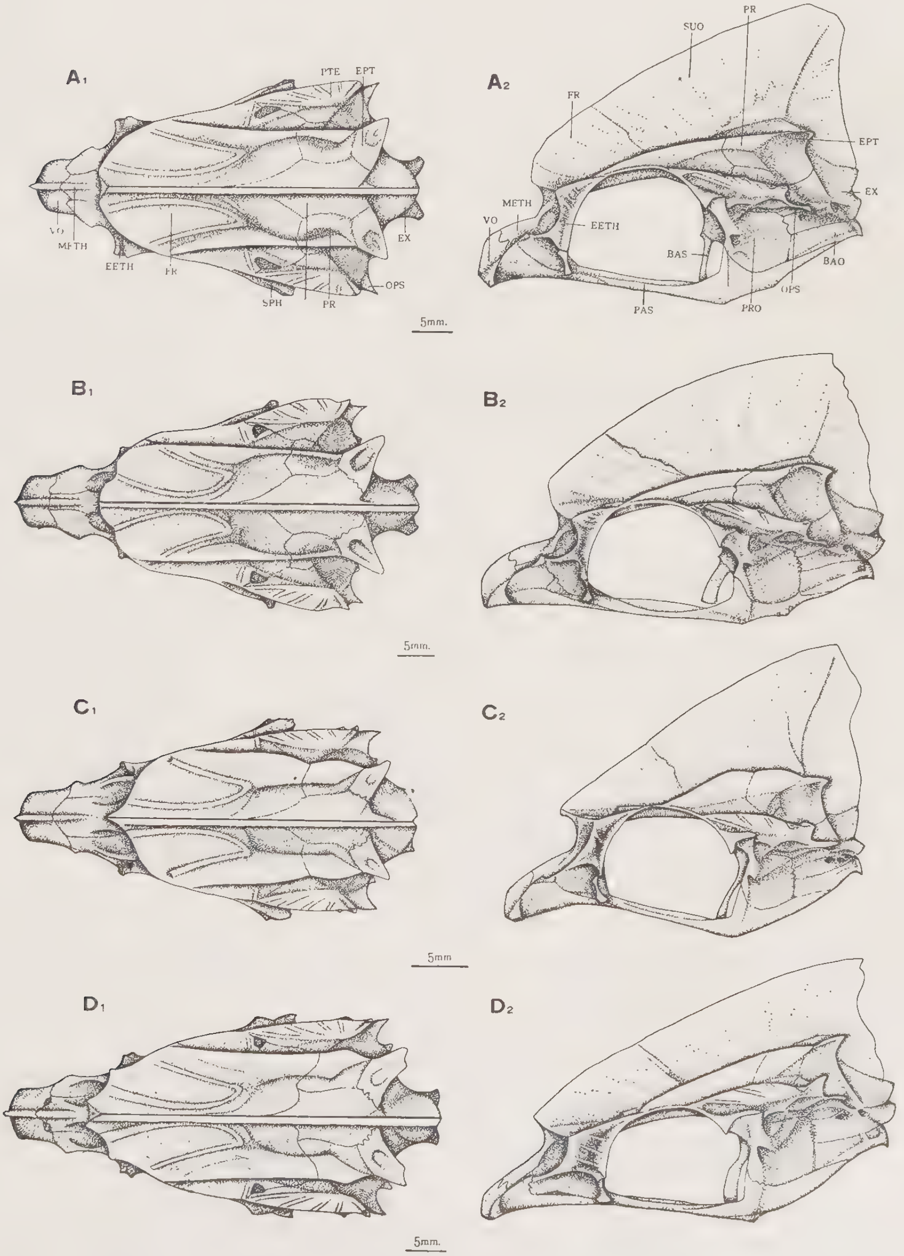

Fig. 4. Upper and lateral aspects of the cranium in 4 species. A, *Carangoides hemigymnostethus*; B, *C.* jordani; C, *Kaiwarinus equula*; D, *Longirostrum delicatissimus*.

In *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. ishikawai*, *C. melampygus*, *C. bixanthopterus* and *Citula plumbeus* it is reduced to a small circular depression, from which a short distance apart dorso-posteriorly the olfactory foramen is perforated (Fig. 2). In *Selaroides leptolepis* and *Trachurops crumenophthalmus* the cavity is very narrow, but deep, and is furnished with the olfactory foramen on its posterior side. *Elagatis bipinnulata* is peculiar in having a shallow, wide cavity which is roofed by the anterior extension of the frontal (Fig. 1, D). An unique example is adduced by *Citula malabaricus*, in which the portion corresponding to the cavity is strongly swollen without retaining any trace of the depression (Fig. 3, C). In the rest of species the cavity is well-developed, being interposed between the ectethmoid and the mesethmoid.

The frontals are paired and are the largest of the cranial bones. They are placed at the top of the cranium between the mesethmoid and the parietal bones. Their anterior halves are raised upward along the midline to form together a median crest, which is the anterior elongation of the fronto-supraoccipital crest. Their posterior halves are not juxtaposed with each other owing to the insertion of the supraoccipital bone between them. Each of the frontals bears two other longitudinal crests on the dorsal surface, one of these continueing posteriorly to the temporal crest and the other to the pterotic crest. The temporal crest ends anteriorly about the middle of the orbital cavity or in its neighborhood in most of the species. In *Carangoides jordani*, *C. hemigymnostethus*, *Citula dinema*, *Atule djeddaba*, *Trachinotus bailloni*, *Naucrates ductor* and *Chorinemus orientalis* the temporal crest reaches the proximity of the anterior boundary of the orbital cavity. The pterotic crest extends along the lateral border of the cranium to the point just behind the anterior end of the temporal crest. In greater part of the cases the anterior end of this crest lies on the posterior boundary of the orbital cavity and is separated from the same end of the temporal crest for a considerable distance. In *Megalaspis cordyla*, *Caranx hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Atropus atropus*, *Alectic ciliaris*, *Trachinotus bailloni*, *Seriola quinqueradiata*, *Naucrates ductor* and *Chorinemus orientalis*, however, the fore ends of the two are close to each other. The portion just outside the median crest is usually depressed. The bone has two longitudinal and one transverse sensory tubes on the dorsal surface. The frontal is united with six bones: posteriorly with the parietal and the supraoccipital, laterally with the sphenotic, ventrally with the alisphenoid, and anteriorly with the mesethmoid and the ectethmoid.

The parasphenoid is an elongate narrow bone running on the ventral surface of the cranium along the midline. It adjoins to four bones. The anterior bifurcated part comes in contact ventrally with the vomer and dorsally with the ectethmoid and the posterior part is connected dorsally with the three bones, basisphenoid, prootic and basioccipital. Ordinarily, the posterior part of the parasphenoid has a notch, behind which the myodome opens. The anterior part of the bone, which forms the floor of the orbital cavity, has either wide and flattened on its ventral surface or narrow and flattened, or highly keeled. The first of these types is found

in the following species: *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor* and *Elagatis bipinnulata*. The last is represented by *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Carangoides jordani*, *C. hemigymnostethus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C.*

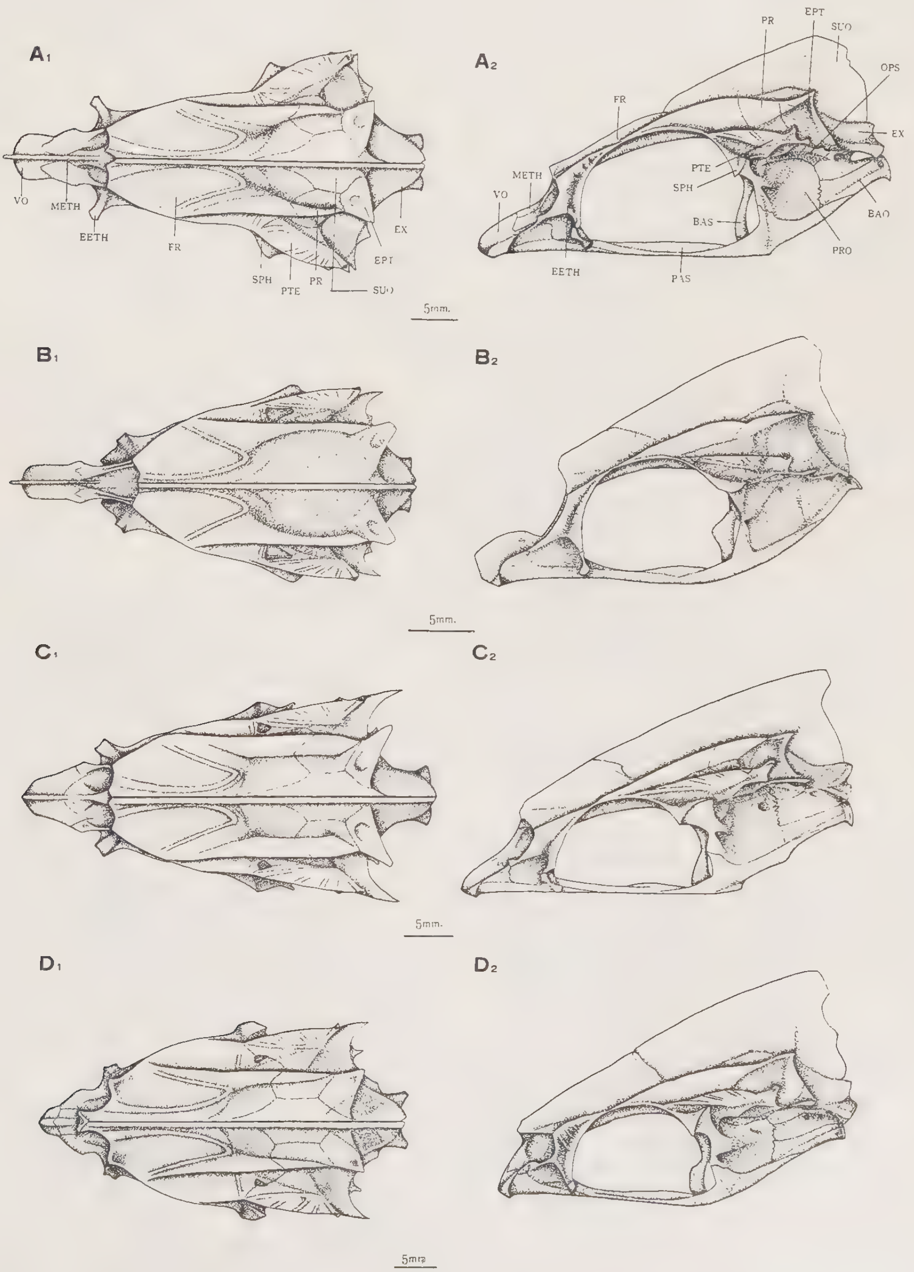

Fig. 5. Upper and lateral aspects of the cranium in 4 species. A, *Trachurops crumenophthalmus*; B, *Selaroides leptolepis*; C, *Atule affinis*; D, *A. djeddaba*.

melampygus, *C. bixanthopterus*, *C. ishikawai*, *Atropus atropus*, *Gnathanodon speciosus*, *Alectis ciliaris* and *A. major*. The rest species belong to the second type. The posterior part of the bone which corresponds to the floor of the myodome is usually moderately round on its ventral border. In *Gnathanodon species*, the anterior half of the ventral border, lying under the prootic, is equipped with a well-developed proturberance which carries a conical cavity opening straight backward. In *Trachinotus bailloni*,

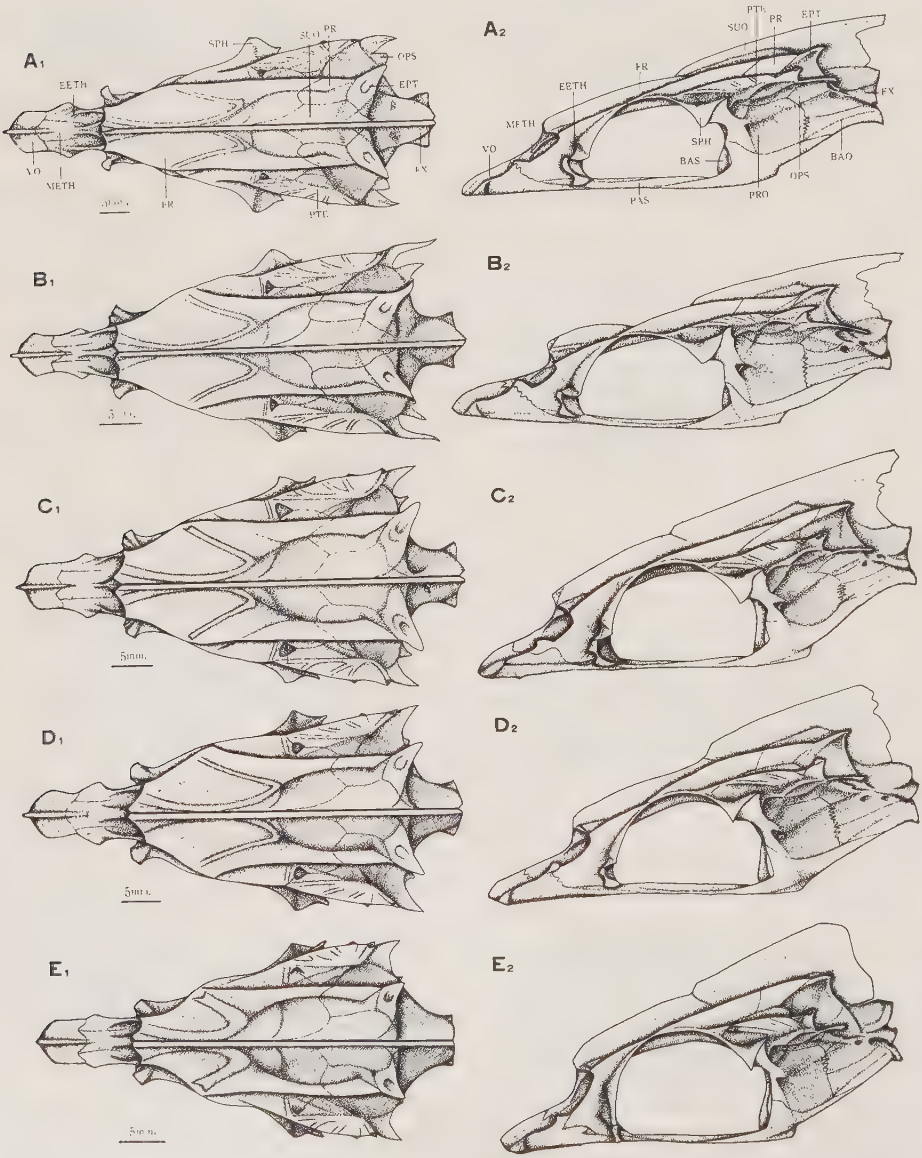

Fig. 6. Upper and lateral aspects of the cranium in 5 species. A, *Decapterus russellii*; B, *D. lajang*; C, *D. muroadsi*; D, *D. maruadsi*; E, *Trachurus japonicus*.

the same border is greatly expanded in its posterior part laterally into a broad and flattened disc, to which the enlarged superior pharyngeals are attached. At the entrance of the myodome and just in front of the prootic the parasphenoid sends off a lateral wing.

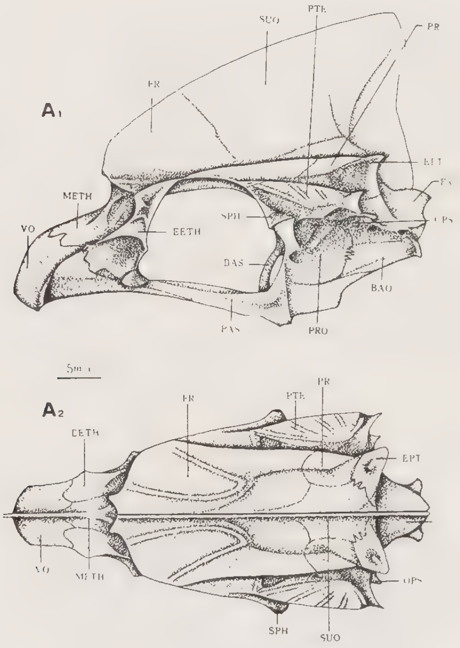

Fig. 7. Upper and lateral aspects of the cranium in *Gnathanodon speciosus*.

Postorbital region of cranium:

The supraoccipital is a median bone situating at the upper posterior angle of the cranium and forming a keystone of the posterior cranial region. It is inserted anteriorly into the two frontals and is interposed in its principal portion between the epiotics as well as between the parietals. It is highly keeled along the midline, constituting together with the median keel of the frontals the fronto-supraoccipital crest. Development of this crest greatly varies in its extent according to the species. In *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Megalaspis cordyla*, *Elagatis bipinnulata* and *Chorinemus orientalis* the height of the crest measured at the center of the brain case is smaller than one fifth the depth of the latter. In *Kaiwarinus equula*, *Carangoides jordani*, *C. hemigymnostethus*, *Caranx melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Citula plumbeus*, *Atropus atropus*, *Uraspis helvolus*, *Gnathanodon speciosus*, *Alectis ciliaris* and *A. major* the crest is vertically strongly expanded, reaching about half as high as the depth of the cranium. The invasion of the bone between the frontals also varies in its extent. In *Kaiwarinus equula*, *Carangoides jordani*, *C. hemigymnostethus*, *Longirostrum delicatissimus*, *Atropus atropus*, *Gnathanodon speciosus* and

Trachinotus bailloni, the supraoccipital extends along the median crest as far forwad as the anterior boundary of the orbit, whereas in *Decapterus russellii*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Megalaspis cordyla*, *Caranx hippos* and *Elagatis bipinnulata* it is confined to reach the posterior boundary of the orbit. In others the fore end of the bone lies exactly above the center of the orbit.

The parietals which are paired occupy the space interposed between the frontal and epiotic on either side. Without meeting on the median, they are widely separated from each other owing to the intervention of the supraoccipital. Each of them is articulated laterally to the pterotic. On the dorsal surface each is armed with a longitudinal crest which runs parallel with the fronto-supraoccipital crest. Forming a part of the temporal crest, the parietal crest joins anteriorly the frontal crest and continues posteriorly to the epiotic process. The parietal crest, though largely oriented longitudinally, shows an outward inclination in relation to the brain case in most of the species.

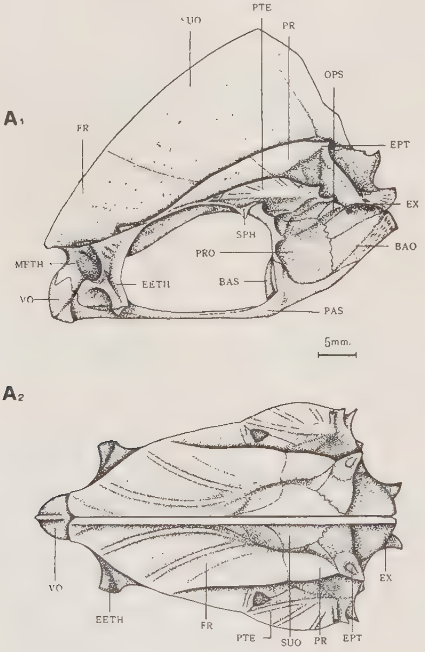

Fig. 8. Upper and lateral aspects of the cranium in *Uraspis helvolus*.

The epiotics are paired and located at the dorso-posterior corner of the cranium. Each of them is hinged anteriorly with the parietal, laterally with the pterotic and medially with the supraoccipital, and is strongly bent downward at the hind end so as to continue to the exoccipital. At the dorso-posterior angle, where each is jointed to the upper arm of the posttemporal, each is prominently produced postero-laterally into the epiotic process. But in *Chorinemus orientalis* the same angle

is prolonged almost straight backward.

The sphenotics are paired and strongly built. They are raised behind the eyes outward and backward into prominent lateral wings and continue to the supraorbital border of the frontals on either side. Each of them forms a suture with the frontal and alisphenoid anteriorly, with the prootic ventrally and with the pterotic posteriorly. The wing-like portion of the bone is usually uneven in its outline and more or less angulated. In *Selaroides leptolepis*, however, it is more or less evently circular (Fig. 5, B). In *Chorinemus orientalis* it describes a zigzag outline on account of the presence of two projections (Fig. 12).

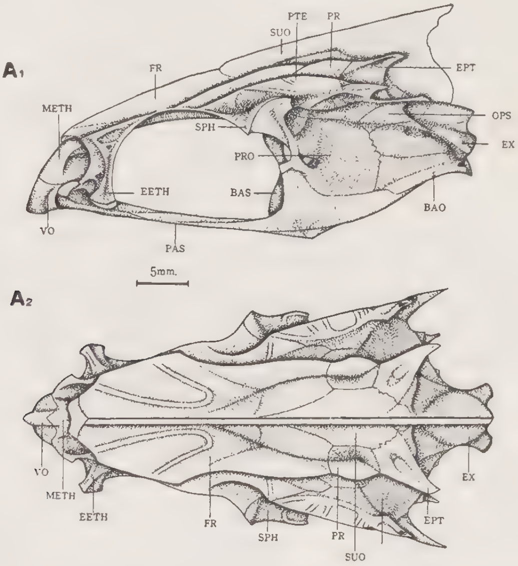

Fig. 9. Upper and lateral aspects of the cranium in *Megalaspis cordyla*.

The alisphenoids are flattened and irregular-shaped, forming the anterior wall of the brain case and the dorso-posterior wall of the orbit. Each of them is articulated to the prootic posteriorly, to the sphenotic dorso-posteriorly and to the basisphenoid ventro-posteriorly, and is covered by the frontal dorsally. In all the members of the family, the alisphenoids of the two sides are widely separated from each other by the intervention of the anterior opening of the brain case. They are continuous on their inner borders to the paired longitudinal ridges present on the lower surface of the frontals. The ridges of both the sides, which reach the ectethmoid, incline toward the midline, but do not come in contact with each other in their entire length in most of the species. Especially in *Trachinotus bailloni*, they are widely apart from each other and run nearly parallel. In *Trachurus japonicus*, *Decapterus russellii*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus*, *Caranx ishikawai*, *Uraspis helvolus*, *Atropus atropus*, *Alectis ciliaris*, *A. major* and *Chorinemus orientalis*, they keep almost in contact with each other on the midline.

The pterotics are paired and form the upper and hinder region of the sides of the cranium. On either side, they are surrounded anteriorly by the frontal, antero-ventrally by the sphenotic and the prootic, posteriorly by the opisthotic and the exoccipital, and medially by the parietal and the epiotic. The dorso-lateral border of each pterotic is raised into a crest which extends as far forward as the frontal.

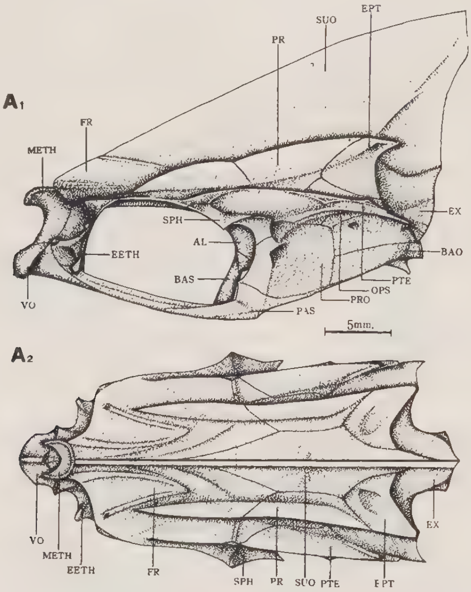

Fig. 10. Upper and lateral aspects of the cranium in *Trachinotus bailloni*.

The pterotic crest carries a series of sensory tubes, radiating outward. *Chorinemus orientalis* and *Alectis major* are peculiar in having the low and bulky crest, on the surface of which the sensory tubes are indistinctly recognizable. In the species exclusive of these two, the crest is rather conspicuous and produced backward into a projection, which is associated underneath with a well-developed spine. In *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. maruadsi*, *D. akaadsi*, *Atule djeddaba*, *A. affinis*, *Seriola quinqueradiata*, *S. purpurascens* and *Naucrates ductor* the spine is strongly prolonged backward, assuming an ensiform appearance (Fig. 1; Fig. 5, C-D; Fig. 6). In *Chorinemus orientalis*, on the contrary, it is produced only slightly and is concealed beneath the posterior projection of the pterotic crest in dorsal view. On the ventral side, the bone bears two depressions for the reception of the articulating head of hyomandibular. The depression which lies in front of the other is rather deep and round, and its anterior wall is formed by the assistance of the sphenotic. The other is elongate fusiform and is confined to the wall of the pterotic. In *Gnathanodon speciosus* and *Selaroides leptolepis* the pterotic encloses at its fore end together with the posterior border of the frontal a very large foramen (Fig. 5, B; Fig. 7). The foramen, which is here termed the pterotic window, is less developed in *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maru-*

adsi, *D. akaadsi*, *Carangoides jordani*, *C. hemigymnostethus*, *Citula dinema*, *Longirostrum delicatissimus*, *Atule djeddaba*, *A. offinis*, *Uraspis helvolus*, *Alectis ciliaris* and *Seriola purpurascens*. It is entirely absent in others.

The basisphenoid, the smallest of cranial bones, is Y-shaped and median in position, lying on the cranial floor between the alisphenoid and the prootic. It has a medio-ventral process descending to the parasphenoid, to which it is attached.

Forming the anterior portion of the lateral wall of the brain case, the prootics are large and paired. They are more or less hexagonal in shape, though somewhat irregular in outline. On either side they are adjoining to the sphenotic and the pterotic dorsally, to the parasphenoid ventrally, and to the opisthotic, exoccipital and basioccipital posteriorly. Their inner wall sends off inward a horizontal shelf, which meets the fellow of the oppsite on the midline so as to provide the myodome with a roof and the cranial cavity with a floor. The myodome is usually well-developed. In the dorso-anterior part of the bone there is a foramen opening to the interior of the orbital cavity in its posterior part.

The opisthotics are paired, squamiform bones which lie on either side of the cranium. Covering the exoccipital-pterotic suture from above and extending as far forward as the posterior border of the pterotic, they form the ventral surface of the cranium. The exoccipital is accordingly widely apart from the pterotic when viewed from below. The opisthotic is invisible in the dorsal view of the cranium except for its posterior projection which is attached to the lower arm of the post-temporal at a point just behind the exoccipital-pterotic suture. The posterior projection is ordinarily small, triangular and nodular in appearance. In *Megalaspis cordyla*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus* and *Caranx hippos* it is well-developed, assuming a triangular shape (Fig. 2, A; Fig. 5, A; Fig. 6; Fig. 9). In *Decapterus russellii* it is relatively larger and wider than in other species (Fig. 6, A).

The exoccipitals are paired, lateral in position, and take part in the formation of the postero-lateral portions of the cranium. They are articulated to six bones: ventrally to the basioccipital, anteriorly to the prootic, and dorsally to the pterotic, the opisthotic, the epiotic and the supraoccipital. Beneath the foramen magnum they carry flattened zygapophyses to be connected with the atlas. The zygapophyses of both the sides usually join each other, but are widely apart in *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus*, *Megalaspis cordyla*, *Longirostrum delicatissimus*, *Atule djeddaba* and *A. affinis*. Moreover, the fishes of the genus *Decapterus* have the zygapophyses placed on the sides of the basioccipital and their ends lying beneath the upper edge of this bone.

The basioccipital is unpaired and median, forming the posterior region of the ventral face of the cranium. It is strongly ossified and articulated posteriorly to the atlas and to the prootic anteriorly. It makes dorso-laterally a suture with the ventral border of the exoccipital, and takes part ventrally in the formation of the myodome together with the parasphenoid. In *Trachinotus bailloni* the bone bears a

large, externally projecting process on the ventral surface on each side (Fig. 10). The myodome can be classified into four types according to the differences in the development of its posterior aperture. In the first type, as represented by *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus*, *Kaiwarinus equula*, *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Longirostrum delicatissimus*, *Atropus atropus*, *Gnathanodon speciosus*, *Selaroides leptolepis*, *Alectis ciliaris*, *A. major*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagatis bipinnulata* and *Chorinemus orientalis*, the myodome has a distinct aperture opening to the exterior in the region of posterior notch of the parasphenoid. The second type, which is the case with *Trachinotus bailloni*, has the myodome aperture narrow and elliptical.

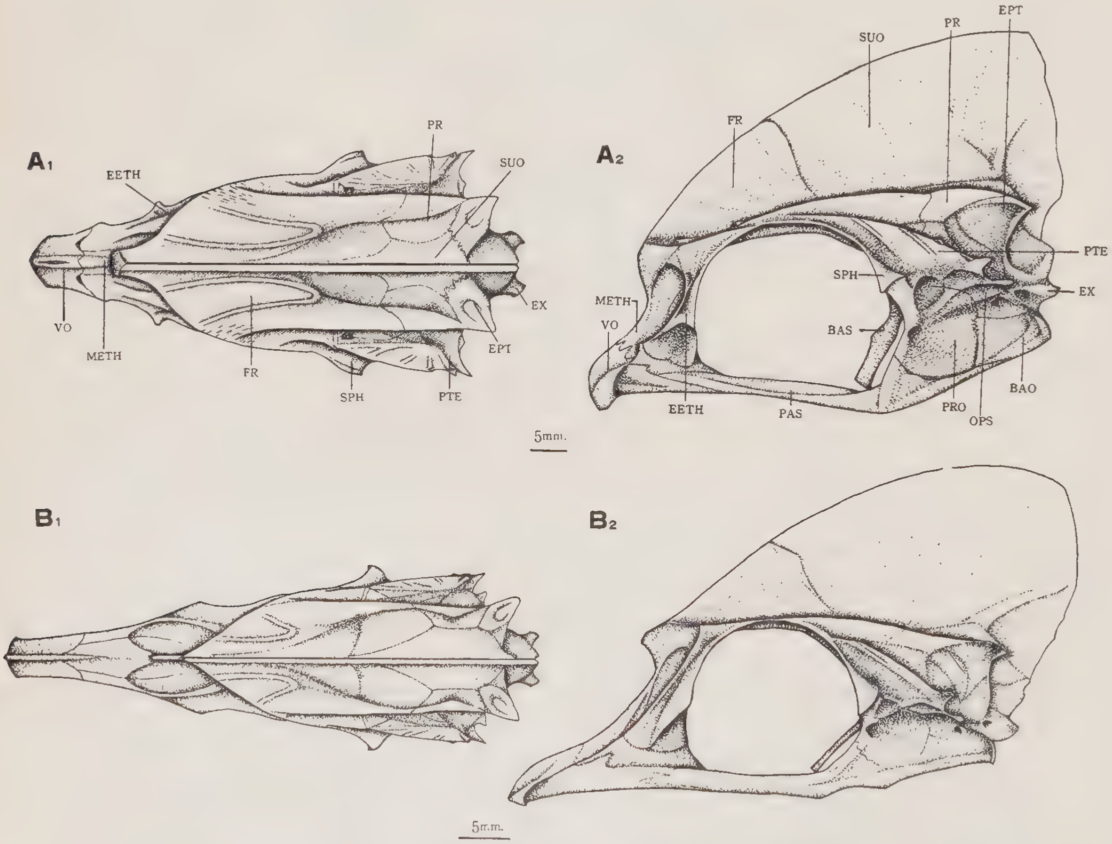

Fig. 11. Upper and lateral aspects of the cranium in 2 species. A. *Alectis ciliaris; B, A. major.*

The third type, as exemplified by the myodomes of *Megalaspis cordyla*, *Carangoides jordani*, *C. hemigymnostethus* and *Atule affinis*, has the posterior perforation so narrow as to hardly permit the insertion of a needle. In the fourth type, comprising *Uraspis helvolus* and *Atule djeddaba*, the myodome is entirely blind outside.

General form of the cranium:

From the facts heretofore a considerable amount of variaties will be expected in the general form of the cranium (Table 2).

In short, it may be well to conclude that the genera with fusiform body, such as, *Trachurus*, *Decapterus*, *Megalaspis*, *Trachurops*, *Atule*, *Selaroides*, *Seriola*, *Naucrates* and *Elagatis*, possess the broad, relatively depressed cranium, whereas the genera with high, compressed bodies, such as, *Carangoides*, *Kaiwarinus*, *Citula*, *Caranx*, *Longirostrum*, *Uraspis*, *Gnathanodon*, *Atropus*, *Alectis*, *Trachinotus* and *Chorinemus*, have a similarly very high, narrow cranium. In other word, there exists a definite tendency that, as the compression of the body progresses, the fronto-supraoccipital crest becomes higher in increasing degree and the cranium grows narrower.

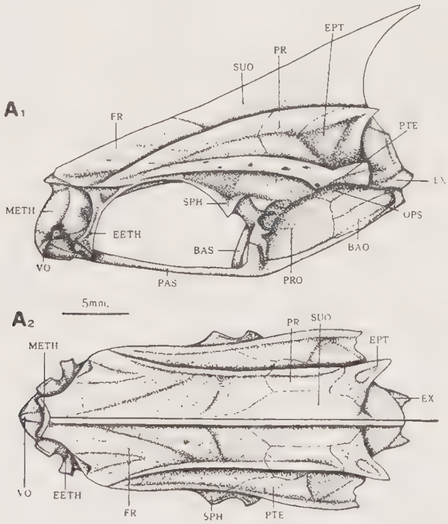

Fig. 12. Upper and lateral aspects of the cranium in *Chorinemus orientalis*.

Discussion

A. Systematic significance of the cranium:

The comparative study of the cranium leads us to conclude that the classification of Japanese carangid fishes can be founded on the following features, some of which are subservient to the separation of genera, or even of subfamilies: (1) extent of the development of mesethmoid-vomerine keel, (2) ventral contour of the median shaft of vomer, (3) dentition of the vomer, (4) presence or absence of the crest armed with villiform teeth on the midline of the median shaft of the vomer, (5) form of the superior portion of the mesethmoid, (6) form of the elevation of the ectethmoid, (7) extent of the development of olfactory cavity, (8) position of the anterior end of the supraoccipital on the frontals, (9) outline of the floor of the orbital cavity, (10) height of the fronto-supraoccipital crest, (11) height of the tem-

Table 2.
Dimensions of various part of cranium as represented by the ratios to its cranial length in various species.

Species	Rostral length	Diameter of orbit	Postorbital length	Height	Width	Interorbital width
Chorinemus orientalis	6. 12	2. 62	2. 00	1. 77	2. 35	2. 75
Trachinotus bailloni	5. 65	2. 82	2. 00	1. 59	2. 06	2. 59
Seriola quinqueradiata	4. 04	3. 63	2. 15	2. 35	1. 85	2. 29
Seriola purpuracens	4. 39	3. 00	2. 19	1. 68	1. 90	2. 42
Naucrates ductor	5. 10	2. 62	2. 28	1. 69	1. 57	2. 10
Elagatis bipinnulata	3. 48	3. 19	2. 42	2. 54	2. 08	2. 82
Megalaspis cordyla	5. 22	2. 88	2. 00	2. 09	2. 04	3. 03
Caranx sexfasciatus	5. 12	2. 70	2. 09	1. 73	2. 18	3. 04
Caranx xanthopygus	5. 00	2. 86	2. 03	1. 57	2. 07	2. 90
Caranx melampygus	3. 60	3. 16	2. 21	1. 63	2. 36	3. 06
Caranx bixanthopterus	3. 73	2. 92	2. 22	1. 64	2. 41	3. 15
Caranx hippos	5. 45	3. 07	1. 71	1. 77	2. 31	3. 33
Caranx ishikawai	3. 46	3. 46	3. 25	1. 34	2. 30	3. 02
Citula plumbeus	4. 26	2. 30	2. 54	1. 26	1. 94	2. 85
Citula dinema	3. 62	2. 85	2. 47	1. 57	2. 09	3. 03
Citula malabaricus	3. 19	2. 26	2. 84	1. 50	2. 17	3. 29
Atropus atropus	5. 06	2. 31	2. 53	1. 23	2. 02	2. 70
Uraspis helvolus	4. 50—4. 39	2. 36—2. 33	2. 52—2. 36	1. 35—1. 30	1. 85—1. 82	2. 36—2. 22
Gnathanodon speciosus	2. 94	3. 33	2. 62	1. 41	2. 08	2. 86
Alectis ciliaris	4. 02	2. 50	2. 64	1. 34	1. 94	2. 64
Alectis major	2. 36	2. 86	3. 61	1. 51	2. 68	3. 72
Carangoides jordani	3. 58	2. 81	2. 54	1. 68	2. 00	2. 63
Carangoides hemigymnostethus	3. 94	2. 70	2. 50	1. 47	1. 85	2. 66
Kaiwarinus equula	4. 10—3. 58	3. 38—2. 58	3. 50—2. 80	1. 78—1. 49	2. 33—1. 98	3. 28—2. 66
Longirostrum delicatissimus	3. 15	3. 28	2. 30	1. 80	1. 63	3. 06
Selaroides leptolepis	4. 00	2. 31	2. 77	1. 88	1. 93	2. 72
Atule djeddaba	4. 77	2. 79	2. 16	1. 74	1. 88	2. 53
Atule affinis	3. 77	2. 96	2. 30	2. 15	2. 13	2. 96
Trachurops crumenophthalmus	4. 04—3. 88	2. 54	2. 78	1. 98—1. 96	2. 02—2. 00	3. 56—3. 58
Decapterus russellii	3. 28	3. 60	2. 44	2. 72	2. 48	4. 00
Decapterus macrosoma	3. 28—3. 27	3. 56	2. 52—2. 47	2. 75—2. 60	2. 75—2. 60	3. 31—3. 02
Decapterus muroadsi	3. 50—3. 48	3. 30—3. 28	2. 61—2. 53	2. 53	2. 16—2. 15	3. 13
Decapterus lajang	3. 37	3. 37	3. 37	2. 63	2. 40	3. 86
Decapterus maruadsi	3. 34—3. 22	3. 44—3. 33	2. 64—2. 54	2. 37—2. 30	2. 25	3. 38—3. 29
Decapterus akaadsi	3. 51	2. 72	2. 75	2. 60	2. 49	4. 30—3. 80
Trachurus japonicus	3. 63—3. 55	2. 75—2. 73	2. 88—2. 77	2. 10—2. 08	2. 16	3. 80—3. 63

poral crest on the parietal, (12) contiguity or discontiguity of the parietals in the interior of the cranium, (13) extent of the development of pterotic crest, (14) shape of the pterotic spine, (15) presence or absence of the pterotic window, (16) shape

of the process of the opisthotic, (17) mutual contiguity or discontiguity of the zygapophyses of the exoccipitals, (18) angle which the exoccipital makes with the basioccipital in lateral view, (19) presence or absence of the posterior opening of the myodome, (20) relative size among the rostral part, orbit and postorbital part, and (21) ratio of depth to width.

B. Consideration on the differentiation of the cranium:

As it may be presumable from the above mentioned, processes in the specialization of the cranium of the Carangidae are rather complicated, and some of the features which appear appropriate for disclosing their phylogeny are not necessarily parallel with one another in making transformation. Although the abundance in varieties is beneficial for formulating a classification, it involves much difficulties to find the phyletic significance of these varieties. The crania can be classified as regard their construction into 8 types, if the account is taken of following characters: (1) extent of the development of the olfactory cavity, (2) height of the fronto-supraoccipital crest and (3) contiguity of the zygapophysis of the exoccipital for the reception of the atlas (Table 3).

Table 3.
8 types of the cranium in Japanese Carangidae.

Type	Characters			Genera
	Zygapophyses of exoccipitals	Fronto-supra-occipital crest	Olfactory cavity	
1	adjoining	low, or somewhat higher	undeveloped	*Seriola* *Naucrates* *Chorinemus* *Trachinotus*
2	adjoining	low	slightly developed	*Elagatis*
3	adjoining	high	undeveloped	*Caranx* *Atropus* *Citula* *Uraspis*
4	adjoining	high	well-developed	*Kaiwarinus* *Carangoides* *Gnathanodon* *Alectis*
5	adjoining	more or less high	well-developed	*Selaroides*
6	slightly apart	more or less high	well-developed	*Longirostrum*
7	widely apart	very low	undeveloped	*Megalaspis*
8	widely apart	low, or somewhat higher	well-developed	*Atule* *Trachurops* *Trachurus* *Dacapterus*

Among the representatives of Type 1, *Seriola* and *Naucrates* possess the most generalized type of crania which, in addition to the three features indicated in Table

3, are characterized by the following points: the rostral part is wide and short, the superior portion of the mesethmoid is slightly produced beyond the diverging fore ends of the frontals into a horizontal process which is disc-like in dorsal aspect and the myodome opens widely backward. It is far from unlikely that the crania of these genera represent the most primitive type of the Carangidae. It may be well to say that the more a genus diverges from them in cranial constitution, the more its specialization proceeds. *Chorinemus* resembles those genera in the general features of the cranium, but is peculiar in having the characters which are not found in those as well as in any others: adjoining of the epiotics in their full length on the midline in the interior of the cranium and low but busky swelling of the pterotic crest. The cranium of *Trachinotus* bears certain points of resemblance to that of *Chorinemus* in general appearance despite the possession of such characteristics as that the superior portion of the mesethmoid is protruded beyond the frontals as a process with an anterior cup-shaped concavity in upper view, that the fronto-supraoccipital crest extends as far forward as the anterior margin of the orbital cavity and is occupied for the greater part by the supraoccipital, that the posterior opening of the myodome is reduced into a small elliptical pore, and that the basioccipital possesses on both sides a large outwardly protruding process. Type 2 resembles to a certain extent *Seriola* and *Naucrates* of Type 1, but is different in the possession of peculiar features that the olfactory cavity is feebly developed and its roof is formed by the anterior extension of the frontal. Type 3 is more strongly modified than those types, since the fronto-supraoccipital crest on the midline is far more greatly elevated. Especially, *Uraspis* is distinct from other genera by that its cranium is rather fragile in structure, and has the posterior opening of the myodome entirely closed. The cranium is again further modified in Type 4 and has a relatively well-developed olfactory cavity on its rostral part. Of this type, *Kaiwarinus* bears a relatively close resemblance to the Type 2 in general constitution of the cranium in contrast to the other three genera which possess own peculiarities. In *Gnathanodon*, the mesethmoid-vomerine keel is highly elevated, assuming the appearance of a thin plate, and the parasphenoid lying under the prootic has well-developed protuberance on its ventral border. In *Alectis*, the ectethmoid is rounded in outline, ascending gracefully toward the frontal without forming any angle. In *Carangoides* the posterior opening of the myodome is very narrow. Type 5 resembles the preceding one in that the zygapophyses of exoccipitals closely adjoin each other and the olfactory cavity is well-developed, but is peculiar in that the fronto-supraoccipital crest is somewhat lower in height, that the mesethmoid-vomerine keel is conspicuously elevated, assuming the appearance of a very thin plate, that the olfactory cavity is very narrow and deep. Type 6 is presumably more strongly specialized than the preceding types in having the zygapophyses of exoccipitals apart from each other and the olfactory cavity well-developed. Generally speaking, the Type 6 goes between the Type 8 which has lower fronto-supraoccipital crest and the Types 3 or 4 which has higher one. Type 7 is in agreement,

on one hand, with Type 8 in being the zygapophyses of exoccipital widely apart and in the very low fronto-supraoccipital crest. It bears, on the other hand, a certain resemblance to the Type 1, since the rostral part is short and wide, the olfactory cavity is absent, and the broad upper portion of the mesethmoid is projecting slightly beyond the diverging fore ends of the frontals. Type 8 is the most specialized of all. It is presumed that this type is derived from the Types 3 or 4, which is furnished with the highly elevated fronto-supraoccipital crest, passing through the Type 6. Of the Type 8, *Atule* resembles the Type 6 in having short and wide rostral part, and *Trachurops* is more or less similar to the Type 5 in the possession of a highly elevated mesethmoid-vomerine keel as well as narrow, deep olfactory cavity.

2. Jaws

Although the osteology of jaws in the carangid fishes has been dealt with by Starks (1911), our knowledge on these structures remains incomplete and meager. Through the more detailed, comparative study with reference to Japanese species the present author could make success in finding some plausible interrelationships among genera, or subfamilies viewed from the structure of jaws and the valid foundation of the taxonomy.

A. Upper jaw;

The supramaxillary is a small flat bone, somewhat resembling a fibula in shape, and lies on the posterior half of the dorsal edge of the maxillary. In the fish taxonomy much stress is frequently laid upon the presence or absence of this bone, which is regarded as one of the criteria in classifying the genera, or subfamilies. Among the species here dealt with, *Trachinotus bailloni* alone is deprived of the supramaxillary (Fig. 15, E). In *Chorinemus orientalis* and *Atule djeddaba* the bone is distinct though much reduced in size, and is placed at the posterior end of the dorsal edge of the maxillary. In the former it is so much reduced as to be only one eighth as long as the maxillary, but in the latter it is somewhat longer being a quarter as long (Fig. 15, D·E). In other species it is again increased in proportional length, occupying about a posterior half or more of the dorsal border of the maxillary. The bone is usually acuminate forward, ending in a sharp point.

The maxillary is slender, elongate and curved, and is situated on the dorsal side of the premaxillary. It has at the anterior end, a prominent, forked head, by which it is connected with the rostral cartilage of the premaxillary, and grows gradually wider towards the back to form the posterior angle of the upper jaw. It varies in its general form rather extensively according to the species. In *Chorinemus orientalis* the bone is a thin, elongate, apically spatulate stick, and is about 8.0 times as long as the height at its posteriormost (Fig. 15, F). In other species it is much stouter, far broader, moderately elongate, spatulate in shape, about 5.0 to 3.0 times

as long as high, and has the outer branch of the forked head more or less thickened and expanded. In *Citula plumbeus*, *C. malabaricus*, *Gnathanodon speciosus*, *Alectis ciliaris* and *A. major*, the named branch is widely expanded and reaches higher than the posterior region of the bone (Fig. 14, A•C; Fig. 17, A•B•C). In *Carangoides jordani*, *C. hemigymnostethus*, *Atropus atropus*, *Longirostrum delicatissimus*, *Selaroides leptolepis* and *Uraspis helvolus* the upper limits of the fore and hind ends lie on same level. In other species, however, the fore end is much less expanded and lies on a level lower than the other end. Usually, the bone is even on its ventral edge except in *Gnathanodon speciosus* which has the same edge undulated (Fig. 17, B).

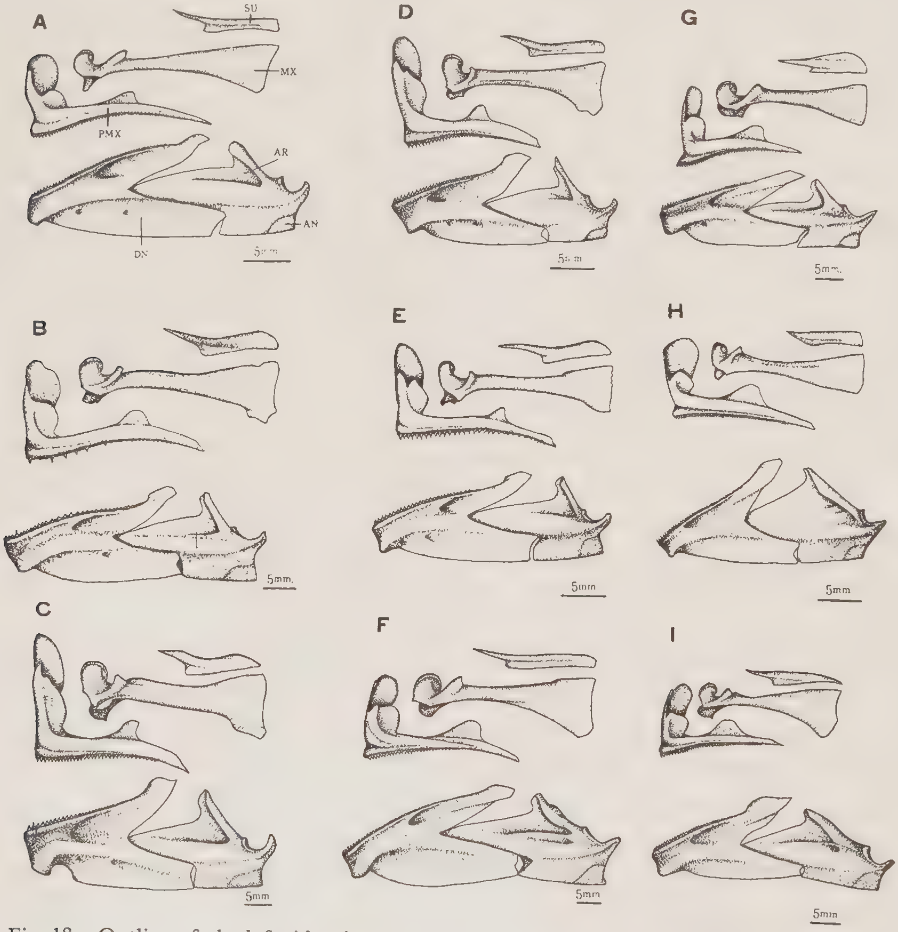

Fig. 13. Outline of the left side of the jaw bones in 9 species. AN, angular; AR, articular; DN, dentary; MX, maxillary; PMX, premaxillary; SU, supramaxillary. A, *Megalaspis cordyla*; B, *Caranx hippos*; C, *C. ishikawai*; *D*, *C. melampygus*; E, *C. xanthopygus*; F, *Seriola quinqueradiata*; G, *S. purpurascens*; H, *Naucrates ductor*; I, *Elagatis bipinnulata*.

The premaxillary constitutes the tip of the snout, lining the upper border of the mouth. Near the fore end the bone is curved inwards, so as to form a sym-

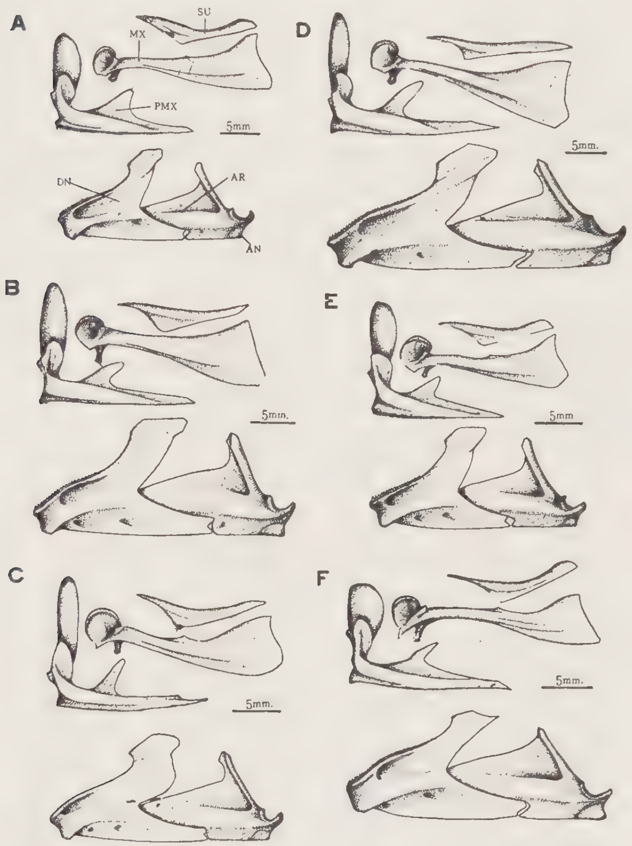

Fig. 14. Outline of the left side of the jaw bones in 6 species. A, *Citula plumbeus*; B, *C. dinema*; C, *C. malabaricus*; D, *Carangoides jordani*; E, *C. hemigymnostethus*; F, *Kaiwarinus equula.*

physis by the union with its counterpart of the opposite side. At the extreme fore end it is produced dorso-posteriorly into the pedicle which is distinctly subdivided into two branches, the anterior one representing the ascending process and the posterior one the articular process. These processes are discriminated from each other by the presence of a V-shaped notch. Usually, the ascending process protrudes higher than the articular one, but in the genera *Trachurops*, *Decapterus* and *Trachurus* the latter is more prominent than the former (Fig. 16). There are some variations in the proportion between the height of the ascending process and the entire length of the premaxillary. In *Selaroides leptolepis*, *Gnathanodon speciosus* and *Alectis major* the height of ascending process equals to the length of the premaxillary, but in others, the height of the former is always smaller than the length of the latter. More precisely, the height is larger than a half of the length in *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Caranx melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Kaiwarinus equula*, *Carangoides jordani*, *C. hemigymnostethus*, *Longirostrum delicatissimus*, *Uraspis helvolus*, *Alectis ciliaris*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor* and *Elagatis bipinnulata*, but smaller

in *Atule djeddaba*, *A. affinis*, *Atropus atropus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos* and *Trachinotus bailloni*, and equaling to, or smaller than one third the length in *Trachurus japonicus*, *Megalaspis cordyla*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus* and *Chorinemus orientalis* (Fig. 15, F; Fig. 16). The premaxillary is loosely attached to the maxillary and is produced on its dorsal border into the postmaxillary process (Allis, 1901), which is applied against the inner face of the premaxillary in most of the species. *Chorinemus*

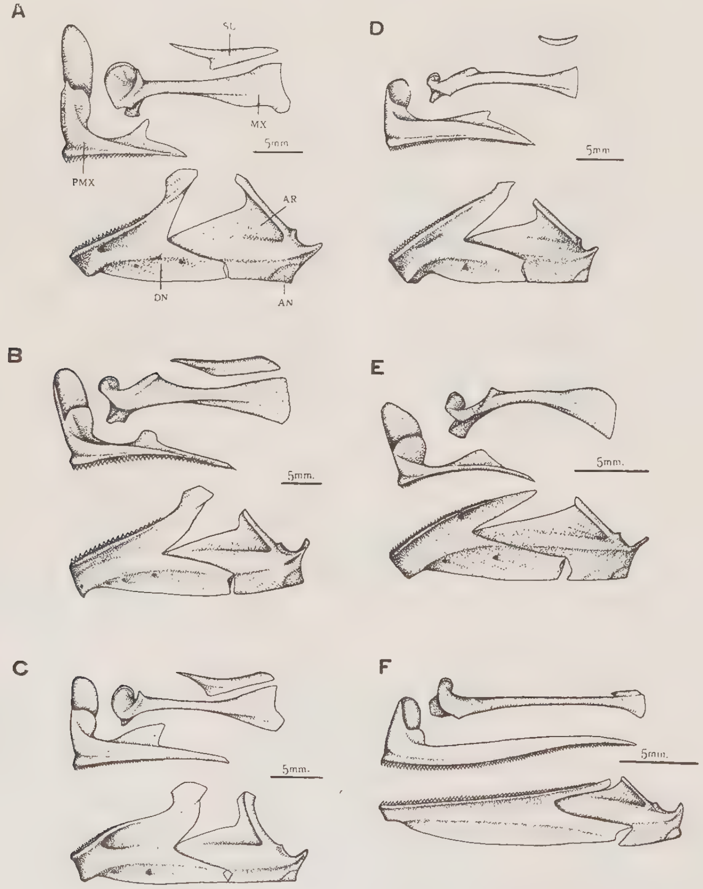

Fig. 15. Outline of the left side of the jaw bones in 6 species. A, *Longirostrum delicatissimus*; B, *Uraspis helvolus*; C, *Atule affinis*; D, *A. djeddaba*; E, *Trachinotus bailloni*; F, *Chorinemus orientalis*.

orientalis makes an exception, since the premaxillary, which is here closely attached to the maxillary extending along entire upper margin, is not equipped with the postmaxillary process (Fig. 15, F). This process varies extensively in shape and size according to the species. In *Trachinotus bailloni*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor* and *Elagatis bipinnulata* the low, relatively broad process is evenly

round on its free margin (Fig. 13, F•G•H•I; Fig. 15, E). In *Megalaspis cordyla*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. melampygus*, *C. bixanthopterus*, *C. hippos*, *C. ishikawai* and *Atropus atropus*, the process more or less resembling the same of the above named species in constitution is much reduced in size (Fig. 13, A•B•C•D•E). In others it is narrowly and sharply projecting dorso-posteriorly. *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi* and *Trachurops crumenophthalmus* possess further slender, elongated process (Fig. 16). Behind the ascending process there is a median piece of cartilage, the rostral cartilage, which bears on the rear surface a groove for the reception of the median keel on the upper surface of the vomer. The cartilage is especially small in size in *Megalaspis cordyla*, *Atropus atropus*, *Atule djeddaba*, *Seriola quinqueradiata* and *Chorinemus orientalis*, being about as high as, or less than one third the length of the premaxillary. Apart from *Selaroides leptolepis*, which possesses a triangular, strongly compressed cartilage (Fig. 17, D), almost all the species have an ovoidal one.

B. Lower jaw:

The dentary is the largest of all the bones of mandible, the fore end of which it constitutes. It is combined anteriorly with its fellow of the opposite side by the symphysis, and deeply forked posteriorly into two arms interposing a V-shaped notch, into which the fore end of the articular is inserted. The articular does not always fill up the notch, but leaves a larger or smaller space just beneath the upper arm of the dentary in most of the species. In *Chorinemus orientalis* no appreciable space is retained (Fig. 15, F). The angle which the two arms make with each other varies with species. It is about 30° in *Chorinemus orientalis*, about 45° in *Megalaspis cordyla*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *Seriola quinqueradiata*, *S. purpurascens* and *Elagatis bipinnulata* (Fig. 13, A•B•E•F•G•H•I). The two arms make a right angle in *Trachurus japonicus*, *Decapterus maruadsi*, *D. akaadsi*, *Citula malabaricus* and *Longirostrum delicatissimus* (Fig. 14, C; Fig. 15, A; Fig. 16, A•E). The upper arm is more or less broad in *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Atule affinis* and *Gnathanodon speciosus*, and the width of this arm in its middle region is greater than that of the same region of the lower arm. In other species the upper arm is somewhat slenderer and about as broad as or broader than the lower.

The articular is a large stout bone, furnished with a long, triangularly pointed process, which is inserted into the V-shaped sinus of the dentary. Posteriorly, the articular is produced into a short, but somewhat stout process, which is curved upward so as to be articulated to the condyle of the quadrate. At the dorsal angle the bone bears another process, which is projecting upward and inclining forward in a varying degree. In *Gnathanodon speciosus* this process is much elongated, with length attaining to about half the height of the bone itself (Fig. 17, B). In *Megalaspis cordyla*, *Trachurops crumenophthalmus*, *Citula plumbeus*, *C. dinema*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *Atule djeddaba*, *Uraspis helvolus*, *Trachinotus bailloni*, *Seriola quin-*

queradiata, *S. purpurascens*, *Naucrates ductor* and *Elagatis bipinnulata* the process is less conspicuous, and with the length not reaching beyond one third the height of the bone.

The angular is a small bone firmly united with the posterior corner of the articular, and constitutes the posterior part of the ventral edge of the mandible.

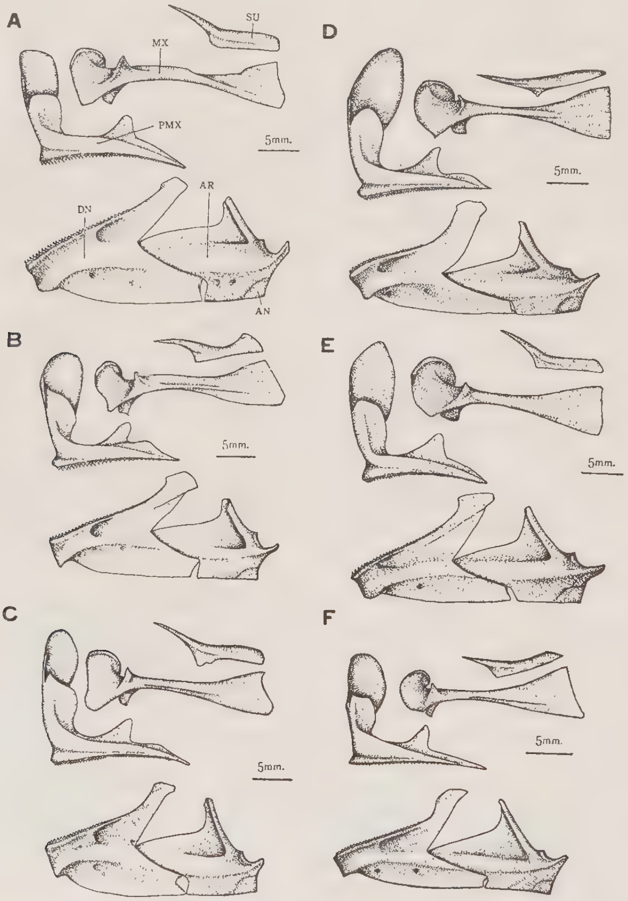

Fig. 16. Outline of the left side of the jaw bones in 6 species. A, *Trachurus japonicus*; B, *Decapterus muroadsi*; C, *D. russellii*; D, *D. russellii*; E, *D. maruadsi*; F, *Trachurops crumenophthalmus*.

C. Dentition:

In *Decapterus macrosoma*, *D. muroadsi*, *D. lajang*, *Gnathanodon speciosus* and *Selaroides leptolepis* teeth are entirely absent from the upper jaw. In other species, they are present without exception, but their arrangement varies according to species. They form a single row in *Decapterus russellii*, *D. macrosoma*, *D. akaadsi*, *Trachurops crumenophthalmus*, *Atule djeddaba*, *Uraspis helvolus* and *Longirostrum delicatissimus*. Of these species, the first and the last are peculiar in having the teeth irregularly set on two or three

rows for a short distance near the anterior end of the upper jaw. On the contrary, in *Trachurus japonicus* similar dental arrangement is found in the region other than the fore end where the dentiton makes a single row. In *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Carangoides jordani*, *C. hemigymnostethus*, *Kaiwarinus equula*, *Atropus atropus*, *Alectis ciliaris*, *A. major*, *Trachinotus bailloni*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagatis bipinnulata* and *Chorinemus orientalis* the teeth are fine and crowded together, forming a narrow band. *Megalaspis cordyla*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus* and *C. ishikawai* are essentially the same as the above named species in the arrangement of teeth, but are different in the outer series of the teeth being stouter and larger than the inner series.

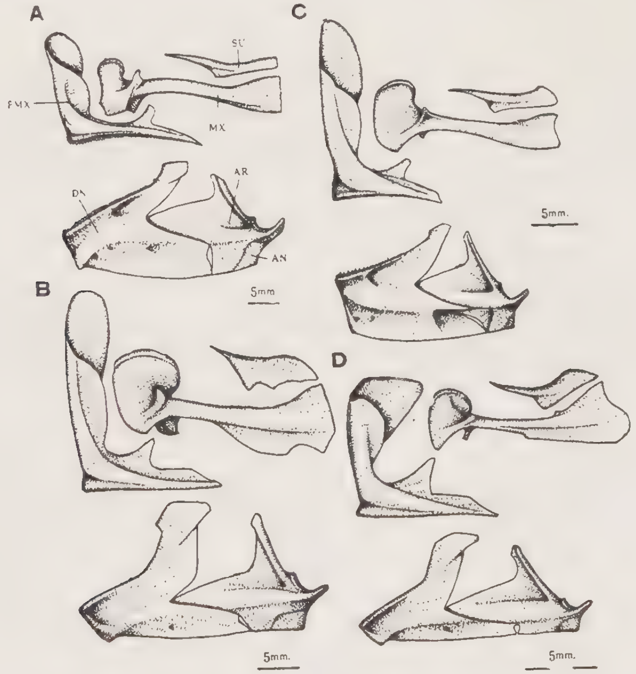

Fig. 17. Outline of the left side of the jaw bones in 4 species. A, *Alectis ciliaris*; B, *Gnathanodon speciosus*; C, *Alectis major*; D, *Selaroides leptolepis*.

The lower jaw is almost always toothed, though toothless in *Gnathanodon speciosus*. The teeth are crowded together forming a narrow band in *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Carangoides jordani*, *C. hemigymnostethus*, *Alectis ciliaris*, *A. major*, *Trachinotus bailloni*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagotis bipinnulata* and *Chorinemus orientalis*, whereas they form a single row in *Trachurus japonicus*, *Megalaspis cordyla*, *Decapterus russellii*, *D. macrosoma*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Longirostrum delicatissimus*, *Selaroides leptolepis*, *Atule djeddaba*, *A. affinis* and *Uraspis helvolus*.

Discussion

A. Systematic significance of the jaw bones:

Although the dentition of the jaws employed as a criterion of differentiating genera and species by Wakiya (1924), their anatomical features have attracted little attention up to the present. The present study clearly indicates that the following features prove their worth as the taxonomic basis: presence or absence of the supramaxillary, shape of the maxillary, difference in the state of attachment of the premaxillary to the maxillary, presence or absence of the postmaxillary process and, if present, the extent of its development, shape of the rostral cartilage, angle of the V-shaped sinus of the dentary, size of the interstice between upper arm of dentary and dorsal edge of articular, and length of the dorsal process of articular.

B. Consideration on the differentiation of the jaw bones:

As regards the important osteological features, the jaw bones of the carangid fishes can first be classified into two major types, one being represented by *Chorinemus* (Type 1) and the other by the rest genera (Type 2). Type 1 bears a closer resemblance to the scombrid fishes rather than to Type 2 in the possession of the non-protractile premaxillary. Moreover, Type 1 is peculiar in the extremely slender, aciform maxillary with a spatulate apex, in the absence of the postmaxillary process, in the close application of the premaxillary to the inside of the maxillary, in the retardation in the development of the rostral cartilage, and in the absence of interosseous space between the upper arm of the dentary and the dorsal edge of the articular.

In Type 2 which involves all other species of the family, the maxillary is moderately elongate and spatulate in shape, the postmaxillary process is invariably present, the premaxillary is rather loosely attached to the inner surface of maxillary, and the interstice between the dentary and articular is present though developing in varying extent. As shown in Table 3 this type can be subdivided further into four subtypes on the basis of the differences in the development of the postmaxillary process and of the ascending process.

In Sub-types 1 and 2 the postmaxillary process is more or less round in shape, and neither acuminated nor produced into a process, whereas in Sub-types 3 and 4 it is triangular, projecting distinctly upwards and backwards. The postmaxillary process may prevent the sidewise dislocation of the premaxillary from the maxillary when the mouth is widely open, and the development of the process may ensure the security for the protrusion of the premaxillary. The two events may thus be correlative with each other. If such a reasoning should be correct, it may be well to conclude that the slender, elongate process is acquired as a necessary consequence of the increase in the protrusion of the premaxillary. The Sub-types 3 and 4 are more specialized than the others in so far as the postmaxillary process is concerned.

Table 4.

4 sub-types of the jaw bones in Japanese Carangidae (Type 2).

<table>
<tr><th rowspan="2">Súb-type</th><th colspan="2">Characters</th><th rowspan="2">Genera</th></tr>
<tr><th>Postmaxillary process</th><th>Ascending process</th></tr>
<tr><td>1</td><td>small, with upper margin round</td><td rowspan="3">longer than articular process</td><td>Megalaspis
Caranx
Atropus</td></tr>
<tr><td>2</td><td>low, but wide, and with upper margiu round</td><td>Seriola
Naucrates
Elagatis
Trachinotus</td></tr>
<tr><td>3</td><td rowspan="2">somewhat narrow, triangular in form, and projecting upward as well as backward</td><td>Citula
Carangoides
Kaiwarinus
Longirostrum
Atule
Selaroides
Gnathanodon
Uraspis
Alectis</td></tr>
<tr><td>4</td><td>shorter than articular process</td><td>Trachurus
Decapterus
Trachurops</td></tr>
</table>

Type 2 is again divisible into two groups on another ground, that is, on the height of ascending process relative to that of articular process. In one group, which includes Sub-types 1, 2 and 3, the former reaches invariably higher than the latter, whereas in the other, which is represented by Sub-type 4, reverse is the case. So far as the author is conscious, the ascending process extends higher than the articular one throughout the percid fishes. Accordingly, it appears reasonable to regard the ascending process of Sub-types 1, 2 and 3 as more primitive than that of Sub-type 4.

3. Suspensorium and opercular apparatus

Although Starks (1911), in his comparative osteology of the carangid fishes, fully dealt with the suspensorium and opercular apparatus, our knowledge on these organs is neither ample nor adequate. It is intended in this occasion to make a comparative study with respect to these skeletal constituents in the Japanese species in order to disclose the interrelationships among genera and subfamilies and to ascertain the validity of the prevailing taxonomy.

Roughly speaking, however, no fundamental difference in the general arrangement of these skeletal elements can be found among the members of this family.

The hyomandibular is a stout, cuneiform bone with a rather long process, the so-called hyomandibular process, which extends downward and slightly forward to reach the symplectic bone. It bears on its outer surface a highly elevated keel

with a sharp edge, behind which the preopercle is firmly attached. The head of the bone is widely expanded and is provided on the upper margin with three zy-

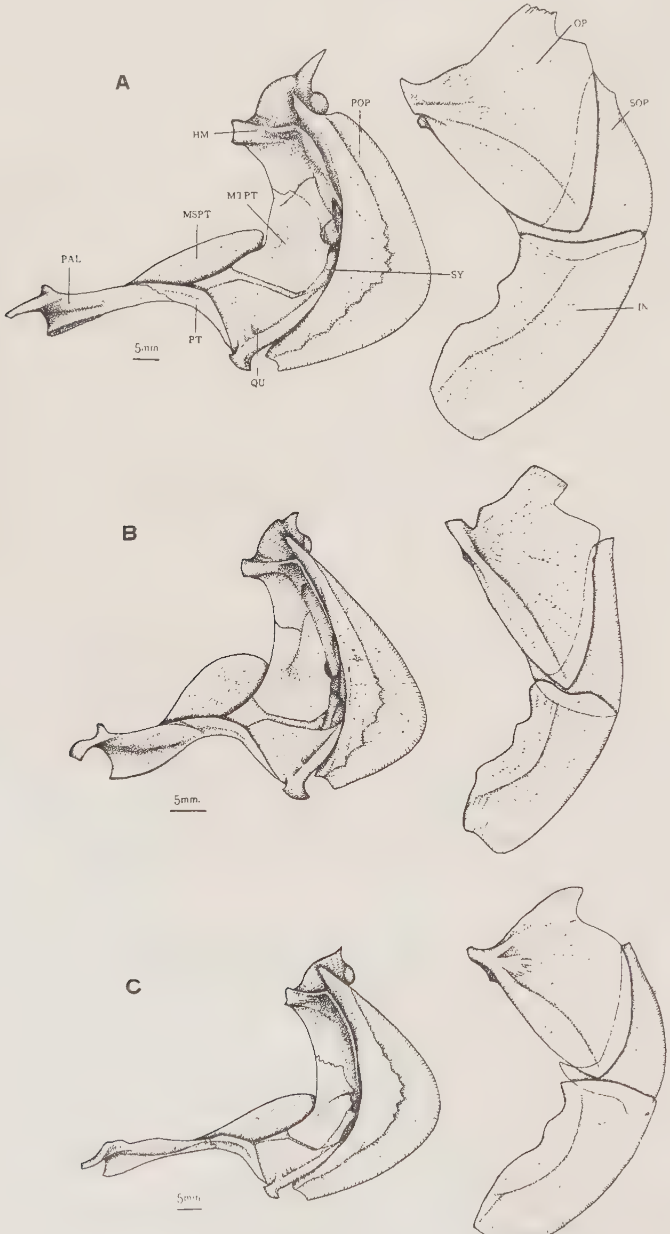

Fig. 18. Outline of the left side of the suspensorium and opercular apparatus in 3 species. HM, hyomandibular; IN, interopercle; MSPT, mesopterygoid; MTPP, metapterygoid; OP, opercle; PAL, palatine; POP, preopercle; PT, pterygoid; QU, quadrate; SOP, subopercle; SY, symplectic. A, *Seriola quinqueradiata*; B, *S. purpurascens*; C, *Elagatis bipinnulata*.

gapophyses. Of these zygapophyses, the posterior member which is articulated to the opercular bone is strongly projecting and distinctly apart from the others. The anterior member is knob-like in shape so as to be articulated to the sphenotic, and the middle member fits in the narrow depression on the pterotic. Differentiation of the anterior zygapophysis from the middle one greatly varies in its extent. In *Chorinemus orientalis* these are widely apart from each other (Fig. 19, B), but in *Atropus atropus*, *Kaiwarinus equula*, *Selaroides leptolepis*, *Gnathanodon speciosus*, *Uraspis helvolus*, *Alectis ciliaris* and *A. major*, these are either continuous to each other, or only slightly distinguishable by a shallow notch (Fig. 21, A•E•F; Fig. 23; Fig. 27, B). The hyomandibular is elongated, narrow and slender in *Citula plumbeus*, *C. malabaricus*, *Atropus atropus*, *Alectis ciliaris* and *A. major*. The length of this bone reaches about 4.4 times the greatest width of the head in *Alectis major*, about 3.8 times in *Alectis ciliaris*, about 3.7 times in *Citula malabaricus*, about 3.5 times in *Atropus atropus*, and about 3.2 times in *Citula plumbeus*.

The metapterygoid is a thin bone, somewhat saddle-like in shape, and is con-

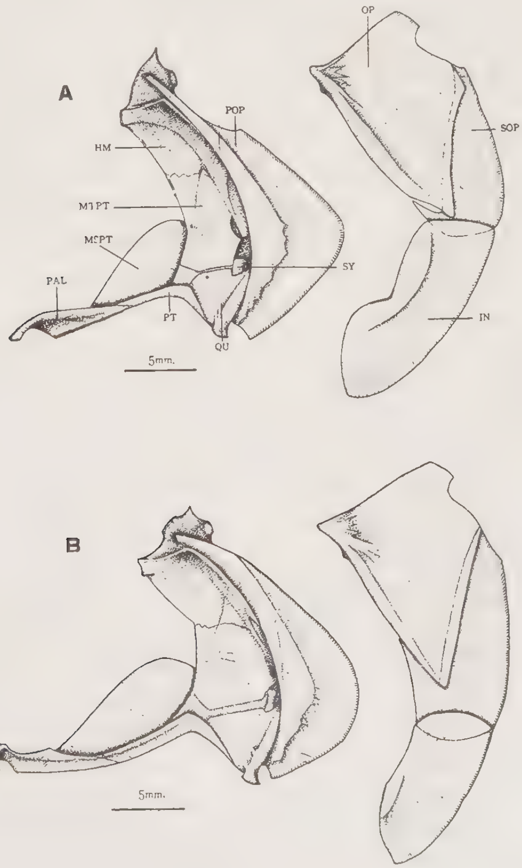

Fig. 19. Outline of the left side of the suspensorium and opercular apparatus in 2 species. A, *Trachinotus bailloni*; B, *Chorinemus orientalis*.

nected on the anterior margin with the quadrate and pterygoid through the mediation of a narrow cartilaginous band, on the lower posterior border with symplectic and hyomandibular process, and at the upper anterior angle with the mesopterygoid. More or less varying in shape, the metapterygoid is broad in *Caranx hippos* and *C. ishikawai* (Fig. 20, A•F), but narrow and elongate in *Citula plumbeus*, *C. malabaricus*, *Atropus atropus*, *Alectis ciliaris* and *A. major* (Fig. 21, A•B•E; Fig. 25). Greater variations can be found in the development of the metapterygoid lamina, in accordance with whose constitution the metapterygoid is divisible into two types. In one, as represented by the structure found in *Gnathanodon speciosus* and *Selaroides leptolepis*, the lamina extends from the inner surface of the metapterygoid as far upward as the lower anterior margin of the hyomandibular, and the interosseous space between them is almost entirely covered by the posterior extension of the metapterygoid (Fig. 23). In the other which involves the rest species the lamina is poorly developed.

The symplectic is a small rod-like bone. Placed along the hind border of the metapterygoid, the posterior half of the symplectic is exposed in side view, but the anterior half, which is inserted into the groove present on the lower part of the inner surface of the quadrate, is invisible.

The quadrate is flattened, broad and flavelliform. On the lower edge it bears a condyle so as to be articulated to the posterior end of the articular. Dorsally it adjoins to the metapterygoid and to the mesopterygoid through the intervention of a narrow cartilage. It joins the pterygoid anteriorly and the preopercle posteriorly, and firmly attaches itself to the symplectic into which it is inserted.

The mesopterygoid constituting a greater part of the orbital floor is a thin lamellar bone, attenuating both forward and backward. This bone reaches about the middle of the dorso-anterior border of the metapterygoid in most of the species, whereas it remains to attain near the fore end of that border in *Caranx* and *Gnathanodon* (Fig. 20; Fig. 23, A). Ventrally it adjoins the quadrate, and extends along the dorsal border of the pterygoid as far forward as the base of the palatine. The size of the mesopterygoid relative to other bones greatly varies. In *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Elagatis bipinnulata*, *Naucrates ductor* and *Chorinemus orientalis* the bone is about as long as, or only slightly longer than the hyomandibular. In the rest of the species, however, the metapterygoid is invariably shorter than the hyomandibular. More precisely, in *Megalaspis cordyla*, *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Carangoides jordani*, *C. hemigymnostethus*, *Kaiwarinus equula*, *Longirostrum delicatissimus*, *Trachurops crumenophthalmus*, *Selaroides leptolepis*, *Atule djeddaba*, *A. affinis*, *Atropus atropus*, *Uraspis helvolus*, *Alectis ciliaris*, *A. major*, *Seriola quinqueradiata* and *S. purpurascens* the metapterygoid is only slightly longer than a half of the hyomandibular, and in *Caranx* and *Gnathanodon* it is even shorter. The upper surface of the bone is ordinarily concave, though nearly flattened in *Caranx* and *Gnathanodon*.

The pterygoid is stout and crooked. The hinder region of the bone comes in

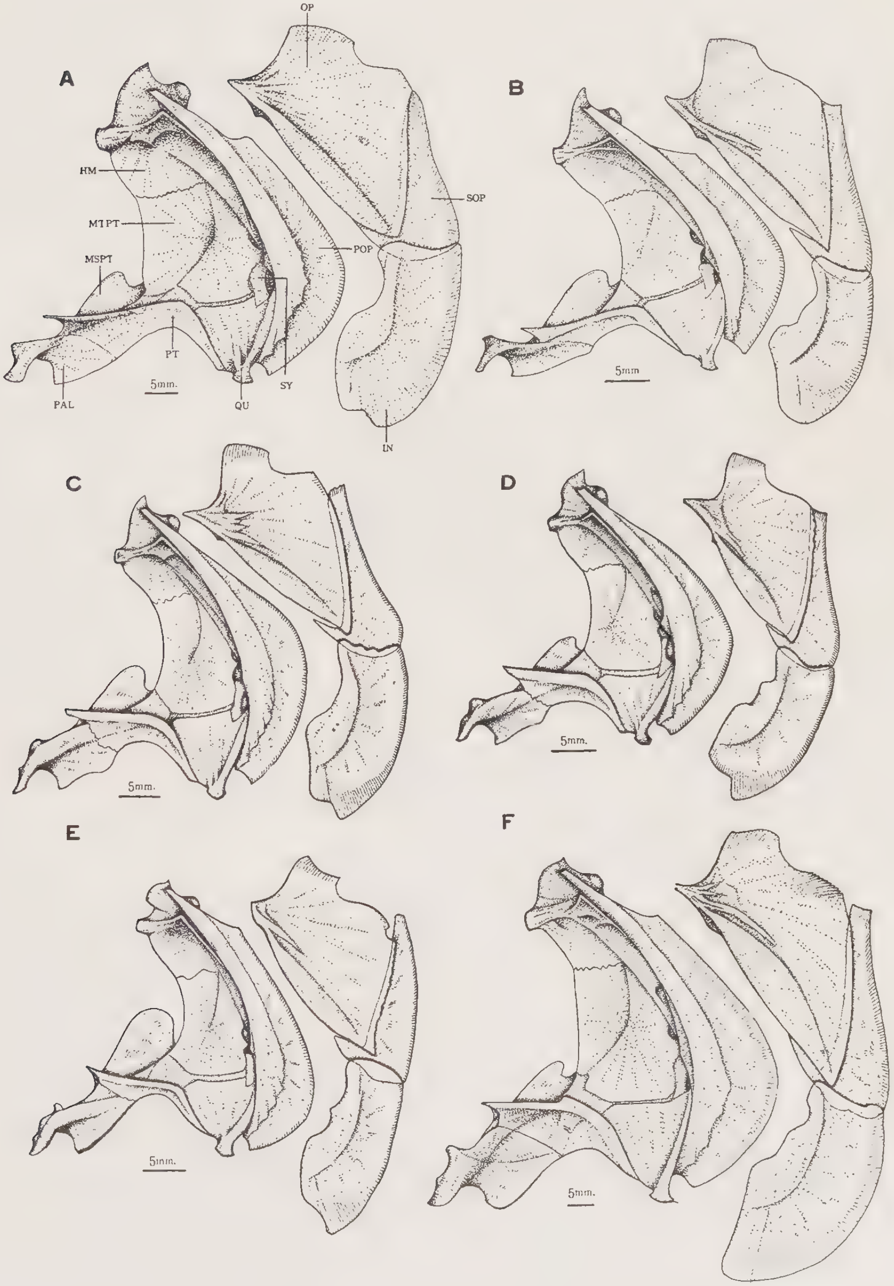

Fig. 20. Outline of the left side of the suspensorium and opercular apparatus in 6 species. A, *Caranx hippos*; B, *C. xanthopygus*; C, *C. melampygus*; D, *C. bixanthopterus*; E, *Citula dinema*; F, *Caranx ishikawai.*

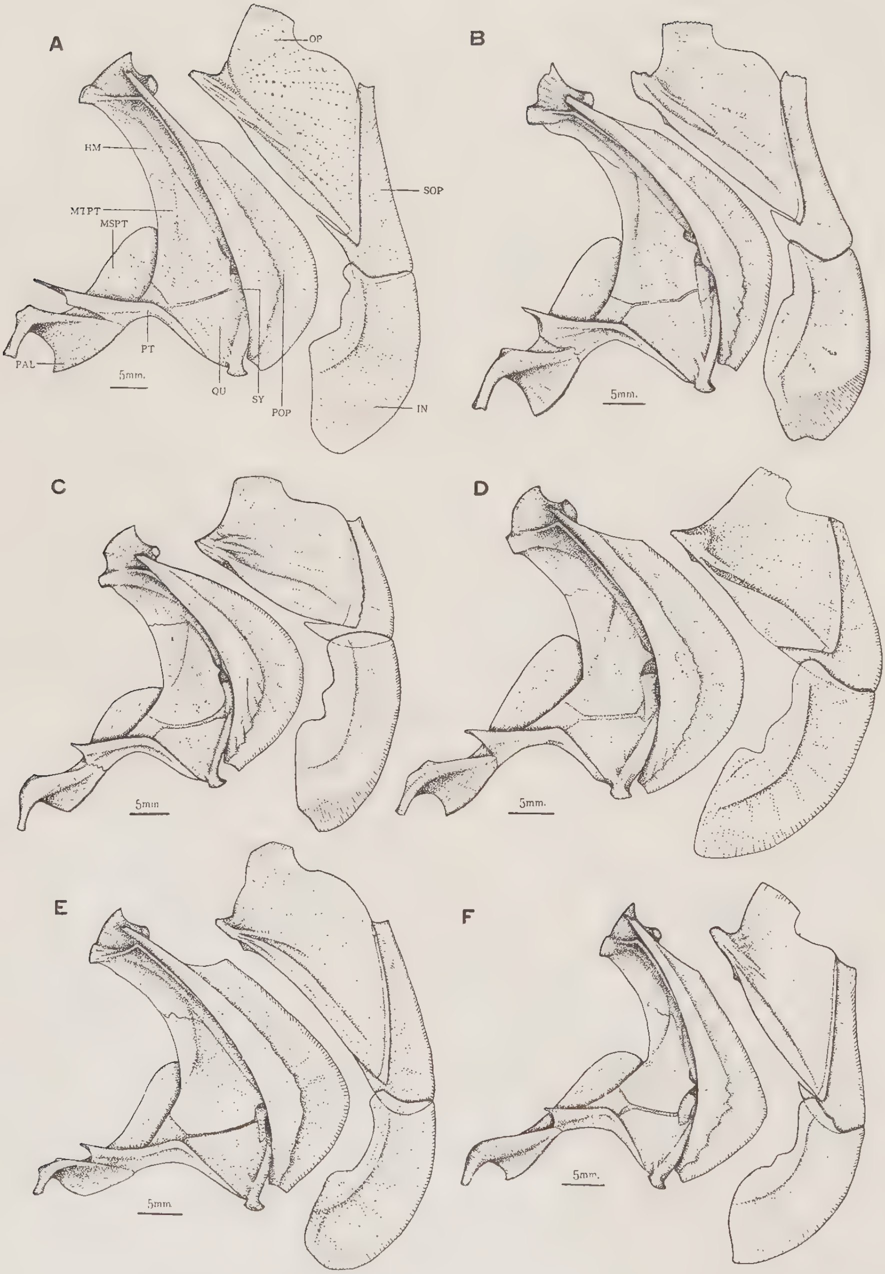

Fig. 21. Outline of the left side of the suspensorium and opercular apparatus in 6 species. A, *Citula plumbeus*; B, *C. malabaricus*; C, *Carangoides jordani*; D, *C. hemigymnostethus*; E, *Atropus atropus*; F, *Kaiwarinus equula*.

contact with the anterior border of the quadrate and is oriented almost vertically to the body axis. At the fore end the pterygoid is prolonged a little upward and forward continuing to the hind border of the palatine. On the dorsal surface it is articulated both to the quadrate and to the mesopterygoid. In company with the posterior end of the palatine it is firmly attached at the fore end of the upper border to the ectethmoid. The fore end is widely expanded and is produced into a short acuminate process in *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Caranx sexfasciatus*,

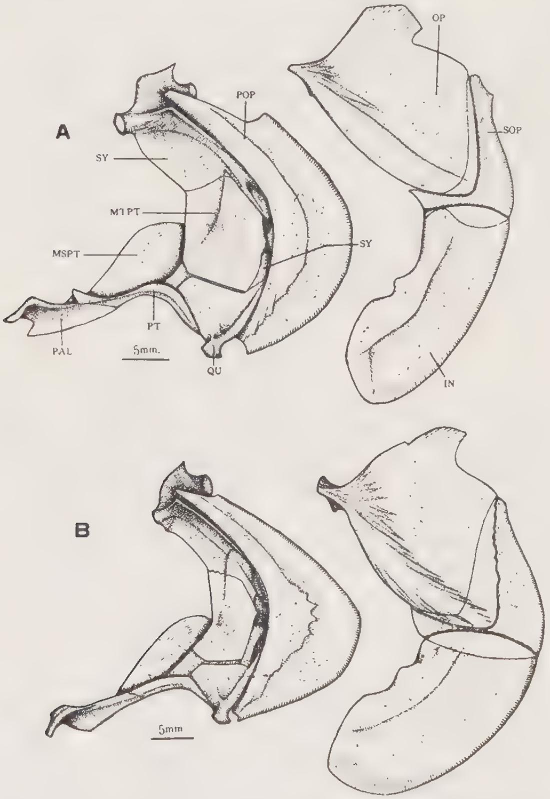

Fig. 22. Outline of the left side of the suspensorium and opercular apparatus in 2 species. A, *Megalaspis cordyla*; B, *Naucrates ductor.*

C. xanthopygus, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Atropus atropus*, *Alectis ciliaris* and *A. major*. The process is less conspicuous in *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Megalaspis cordyla*, *Trachurops crumenophthalmus*, *Kaiwarinus equula*, *Carangoides jordani*, *C. hemigymnostethus*, *Longirostrum delicatissimus*, *Atule djeddaba*, *A. affinis*, *Selaroides leptolepis*, *Gnathanodon speciosus* and *Uraspis helvolus*. The pterygoid is rather slender and deprived of freely projecting process in *Seriola*, *Naucrates*, *Trachinotus* and *Chorinemus* (Fig. 18; Fig. 19). As a rule, the bone is angularly curved at about the middle of its axis, though straightened only in *Trachurops crumenophthalmus* (Fig. 24, A).

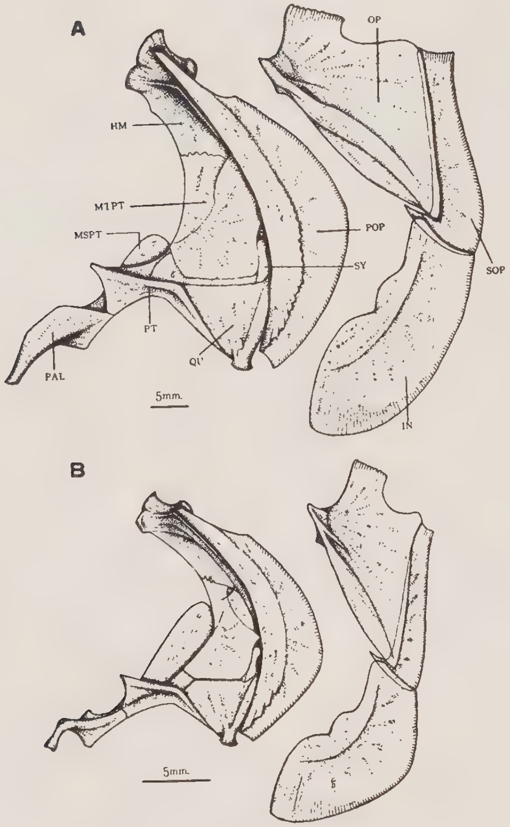

Fig. 23. Outline of the left side of the suspensorium and opercular apparatus in 2 species. A, *Gnathanodon speciosus*; B, *Selaroides leptolepis*.

The palatine is a stout bulky bone, fastened posteriorly to the pterygoid and dorsally to the metapterygoid. It is produced in front into the strong, forwardly projecting prepalatine process, the fore end of which is combined with the anterior portion of the maxillary by the intervening ligament. The prepalatine process is expanded sidewise in *Chorinemus orientalis*. On the upper surface, the palatine is raised into a prominent longitudinal crest extending from the base of the prepalatine process to the anterior border of the pterygoid. On the lower and inner sides the bone is crowded with the villiform teeth which form a band. In *Seriola quinqueradiata* and *S. purpurascens* the dentate band is wide and long, showing an elliptical shape. In *Trachurus japonicus*, *Decapterus lajang*, *D. maruadsi*, *D. akaadsi* and *Trachurops crumenophthalmus*, the band is much narrower and located near the lower margin of the bone. *Decapterus macrosoma*, *D. muroadsi*, *Atule djeddaba*, *Selaroides leptolepis*, *Gnathanodon speciosus* and *Uraspis helvolus* are toothless on the bone in queation. The palatine of *Uraspis helvolus* has two antero-posteriorly arranged facets on the upper and inner surfaces. The posterior facet to which the lower edge of the ectethmoid is tightly

fastened is larger in size than the anterior one, into which an elaborate ligament arising from the ascending process of the premaxillary is inserted. In the rest species these facets are indistinct. Finally, the palatine is somewhat variable in its shape according to the species. Although it is usual with this bone to show a subrectangular shape, this is cuneiform in *Trachinotus bailloni* and *Chorinemus orientalis* (Fig. 19), widely expanded in *Citula*, *Caranx* and *Alectis*, and narrow and slender in *Trachurus*, *Decapterus*, *Trachinotus* and *Chorinemus*.

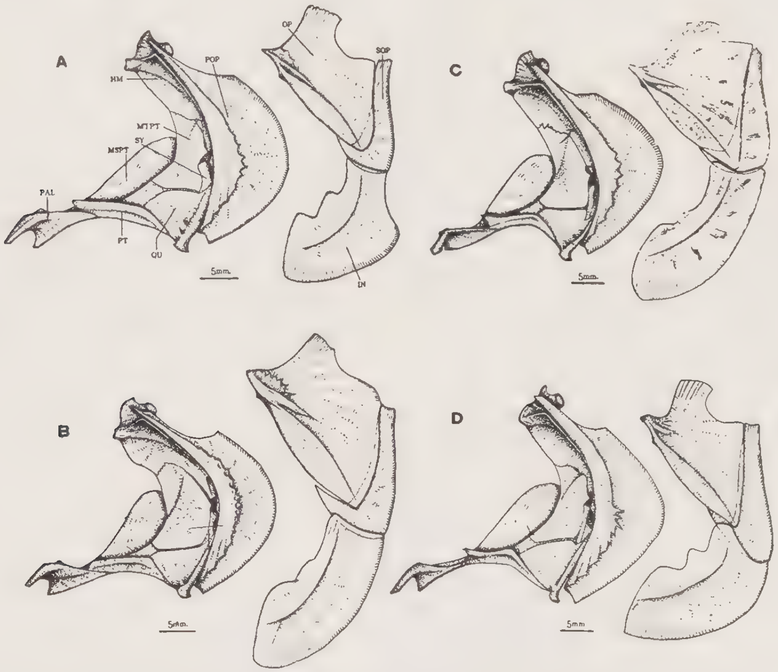

Fig. 24. Outline of the left side of the suspensorium and opercular apparatus in 4 species. A, *Trachurops crumenophthalmus*; B, *Atule affinis*; C, *A. djeddaba*; D, *Trachurus japonicus*.

The preopercle is large-sized, flattened and closely applied to posterior margin of the suspensorium. The upper half of the anterior margin of the preopercle is firmly attached to the posterior side of the prominent keel of hyomandibular. The lower half of the same margin extends antero-ventrally to reach the suspensory angle of the mandible, and is in contact topographically dorsally with the metapterygoid, symplectic and quadrate. The posterior margin is even and is armed neither with dentition nor with spinulation. On the anterior marginal region of the bone, a tubular structure enclosing the lateral sensory canal runs lengthwise to continue to the mandible. Similarly to other bones, the preopercle is variable in its configuration according to the species. On the posterior side, this bone is more or less protruding backward. Protrusion is conspicuous in *Decapterus*, *Naucrates* and *Trachinotus* (Fig. 19, A; Fig. 23, B; Fig. 26), but less so in *Alectis major* (Fig. 25, B).

Besides, the bone shows some generic differences with respect to the width relative to the length. In *Trachurus*, *Megalaspis*, *Decapterus*, *Trachurops*, *Longirostrum*, *Atule*, *Seriola*, *Naucrates* and *Trachinotus* the greatest width is smaller than one third of the length, while in others larger.

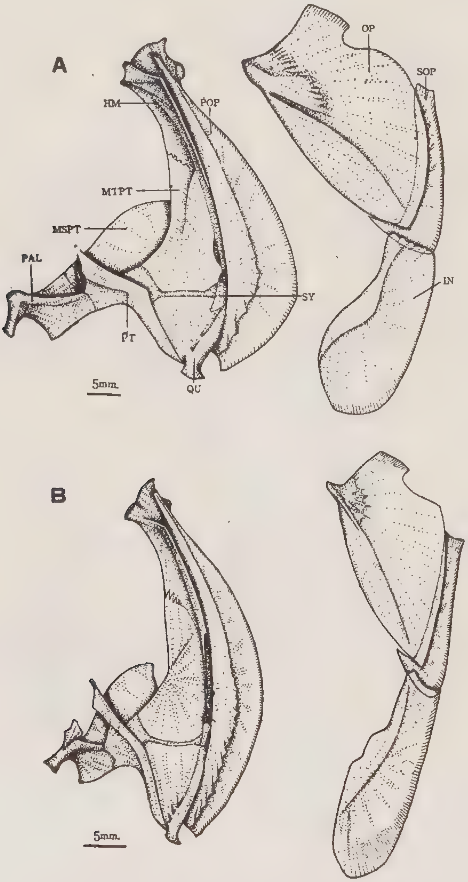

Fig. 25. Outline of the left side of the suspensorium and opercular apparatus in 2 species. A, *Alectis ciliaris*; B, *A. major*.

The opercle is a large flattened bone, somewhat rhomboidal in shape, and with a V-shaped notch on the posterior free margin. The bone has at the antero-dorsal angle a well-developed facet into which the round knodular process of the hyomandibular is inserted. The anterior region of the bone is wrapped by the preopercle and the ventral region lies outside the dorsal marginal region of the subopercle. Length of the opercle relative to that of the interopercle greatly varies. The opercle is longer than the interopercle in *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Kaiwarinus equula*, *Atropus atropus*, *Alectis ciliaris* and *Seriola purpurascens*, about as long in *Trachurus japonicus*, *Megalaspis cordyla*, *Trachurops crumenophthalmus*, *Carangoides jordani*, *C.*

hemigymnostethus, *Longirostrum delicatissimus*, *Gnathanodon speciosus*, *Selaroides leptolepis*, *Uraspis helvolus*, *Alectis major*, *Naucrates ductor* and *Trachinotus bailloni*, but distinctly shorter in *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Atule djeddaba*, *A. affinis*, *Seriola quinqueradiata* and *Elagatis bipinnulata*.

The subopercle is a thin plate, gradually narrowing towards dorso-posterior angle. Along the anterior marginal area the bone is covered by the posterior margin of the opercle. The antero-ventral corner, showing an upward flexure for a short distance, terminates in a pointed tip. Entire ventral border is concealed beneath the interopercle.

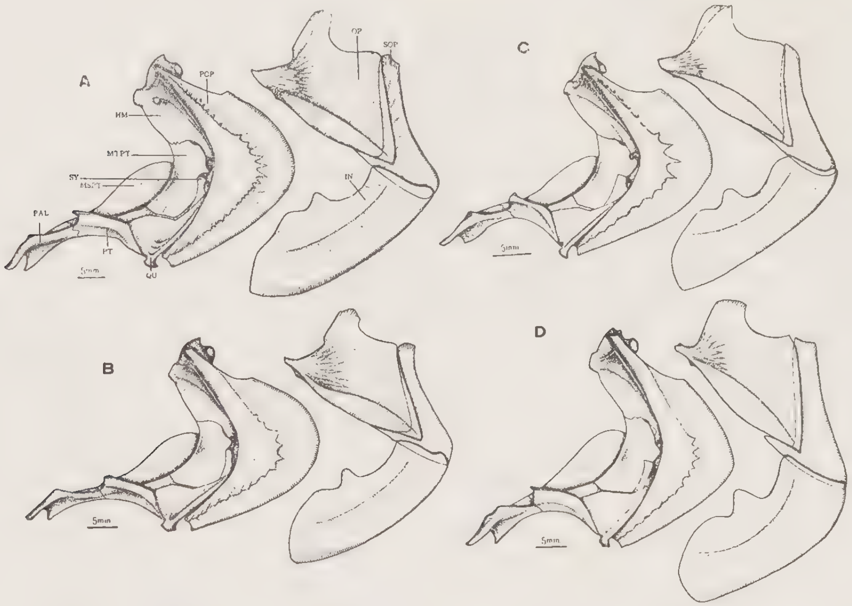

Fig. 26. Outline of the left side of the suspensorium and opercular apparatus in 4 species. A, *Decapterus russellii*; B, *D. muroadsi*; C, *D. lajang*; D, *D. maruadsi*.

The interopercle is somewhat thickened and hidden under the preopercle in its upper part, but covers on posterior side a small antero-ventral marginal area of the subopercle. An elaborate check-ligament arising from the fore end of the interopercle extends forward so as to be firmly fastened to the angular bone. The ventral margin of the bone is gracefully arched in most of the species. *Trachurops crumenophthalmus*, however, makes an exception, since the same margin is concave in its upper one third in contrast to the convexity of the rest region, thus making an obtuse angle at the junction of the two (Fig. 24, A).

The axes of the opercle and of the interopercle make an angle larger than 90° in most of the cases. They make, however, an acuter angle in *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi* and *D. akaadsi* (Fig. 26).

There are some generic differences with respect to the proportion between the

combined length of the suspensorium and opercular apparatus and their height. For convenience's sake, the length is represented by the distance from the anterior extremity of the prepalatine process to the posterior margin of the preopercle and the height is taken as the distance between the pivot of the quadrate and the apex of the hyomandibular. The length is usually larger than the height in *Trachurus*, *Megalaspis*, *Decapterus*, *Trachurops*, *Kaiwarinus*, *Carangoides*, *Longirostrum*, *Atule*, *Selaroides*, *Seriola*, *Naucrates*, *Elagatis*, *Trachinotus* and *Chorinemus*, both are equal in *Caranx Atropus*, *Uraspis* and *Gnathanodon*, and the length is much smaller in *Citula* and *Alectis*.

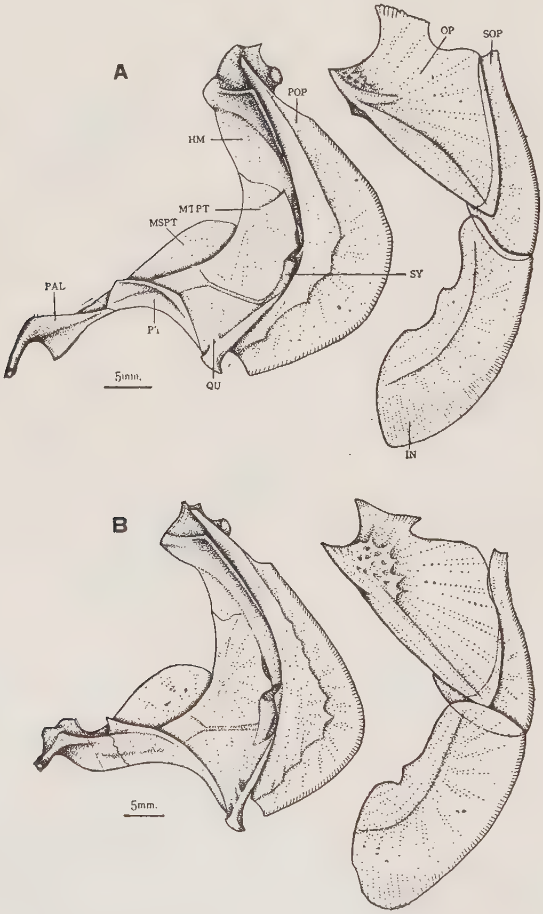

Fig. 27. Outline of the left side of the suspensorium and opercular apparatus in 2 species. A. *Longirostrum delicatissimus*; B, *Uraspis helvolus*.

Discussion

A. Systematic significance of the suspensorium and opercular apparatus:

So far as the suspensorium and opercular apparatus are concerned, their struc-

tural differences have, up to the present, provided us with no sound grounds for classifying the Carangidae. The present study indicates that the following characters are subservient to the classification of this family: development of the metapterygoid lamina, relative size of the mesopterygoid, shape of the anterior part of pterygoid, direction of the prepalatine process, angle interposed between the axes of the opercle and interopercle, shape of the head of hyomandibular, general form of palatine, presence or absence of the palatine teeth, relative width of the preopercle, relative length of the opercle, and ratios of the height of the suspensorium and opercular apparatus to their lengths. Of these characters, the first five are to be regarded as more essential than the others. The metapterygoid lamina is well-developed in *Selaroides* and *Gnathanodon*, but undeveloped in most of the others. The presence of this lamina, therefore, may be regarded as one of the important characteristics of these genera. As stated before, the general shape of the mesopterygoid varies, and the genera *Caranx* and *Gnathanodon* are distinguishable from others by the possession of smaller, more flattened one. The anterior part of the pterygoid also shows generic differences in its shape. Subfamilies Trachinotinae, Naucratinae and Chorineminae are peculiar in the possession of the slender, forwardly projecting pterygoid, which may, accordingly, serve as one of the distinctive characters to be involved in the diagnoses of the subfamilies. Chorineminae is unique in that the prepalatine process is expanded laterally instead of antero-ventrally. This provides another important characteristic of the subfamily. Apart from *Decapterus*, all the genera have the angle interposed between opercle and interopercle larger than a right angle. The angle smaller than 90° in *Decapterus* may effectively be utilizable in distinguishing this from all others.

B. Consideration on the differentiation of the suspensorium and opercular apparatus:

In view of the aforementioned fact, the suspensorium and opercular apparatus in the Japanese carangid fishes appear to be divisible with respect to their osteological features into four types as shown in Table 4. Above all characters, the shape of the anterior part of the pterygoid and the ratio of the height of the suspensorium and opercular apparatus to their combined length are particularly noteworthy.

With reference to the configuration of the anterior part of the pterygoid three distinct types are recognizable in Japanese Carangidae. In the first type, which involves *Seriola*, *Naucrates*, *Elagatis*, *Trachinotus* and *Chorinemus*, the pterygoid is elongate and slender, but not produced into an upwardly directing process at its fore end. In the second type which is represented by *Atropus*, *Gnathanodon*, *Uraspis*, *Kaiwarinus*, *Carangoides*, *Megalaspis*, *Longirostrum*, *Selaroides*, *Atule*, *Trachurops*, *Trachurus* and *Decapterus*, the bone is somewhat enlarged in the anterior portion and produced into a short process at the dorso-anterior corner. In the last type, as exemplified by *Caranx*, *Citula* and *Alectis*, the anterior portion is more widely enlarged and more strongly elongated. So far as the author is aware, the pterygoid is usually widened at the

middle portion tapering towards both extremities throughout the percid fishes. This tells that the first type is more primitive than the others. As to the enlargement of the pterygoid, this appears to be correlated positively with the increase in the body height as well as with the decrease in the body width. Such being the case, so far as the pterygoid is concerned, the second and third types may be considered as more highly specialized than the first type, and the third one is more advanced than the second one in evolutional history, as this may be indicated by the possession of longer and sharper projection at the dorso-anterior corner.

Table 5.
4 types of the suspensorium and opercular apparatus in Japanese Carangidae.

Type	Characters		Genera
	Pterygoid	Height of the apparatus	
1	neither enlarged, nor produced at the dorso-anterior angle	smaller than, or subequal to the length	*Seriola* *Naucrates* *Elagatis* *Trachinotus* *Chorinemus*
2	somewhat enlarged and slightly produced at the dorso-anterior angle		*Atropus* *Gnathanodon* *Uraspis* *Kaiwarinus* *Carangoides* *Megalaspis* *Longirostrum* *Selaroides* *Atule* *Trachurops* *Trachurus* *Decapterus*
3	widely enlarged and produced at the dorso-anterior corner into an elongate process		*Caranx*
4		much larger than the length	*Citula* *Alectis*

The Japanese Carangidae can be assorted into two types with reference to the height and length of the suspensorium and opercular apparatus. In most of the genera the height of the apparatus is subequal to the length, or somewhat smaller, whereas in *Citula* and *Alectis* the height is larger than the length. Increase in this height appears to originate in the increase of body height as well as in compression of body. It may be well to say, therefore, that less high apparatus is more primitive than the higher one.

Considering from these facts, we may reach the conclusion that Type 4 represents the most highly specialized form and Types 3, 2 and 1 follow in due order.

4. Hyoid apparatus

Starks (1911), in his osteological study of the Carangidae, gave a brief de-

scription on the hyoid apparatus, but he was unware of the significance of this apparatus in classifying the family. The number of branchiostegals and the configuration of the bones constituting the apparatus appear to provide us with a certain clue in discloseing probable relationships among genera, or subfamilies.

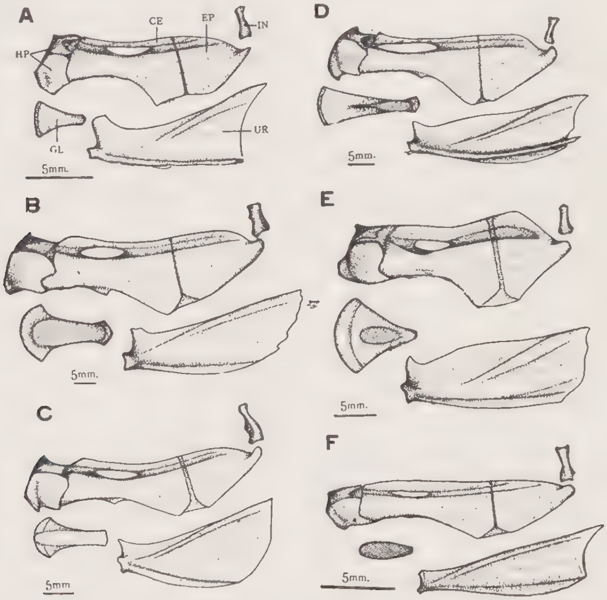

Fig. 28. Outline of the left side of the hyoid apparatus in 6 species. EP, epihyal; CE, ceratohyal; GL, glossohyal; HP, hypohyal; IN, interhyal; UR, urohyal. A, *Trachinotus bailloni*; B, *Seriola quinqueradiata*; C, *S. purpurascens*; D, *Elagatis bipinnulata*; E, *Naucrates ductor*; F, *Chorinemus orientalis.*

The glossohyal is unpaired, representing the most anterior element of the hyoid apparatus, and gives support to the tongue muscle. Widening forward, it is clavate, spatulate, or flabelliform in shape, and is oriented horizontally. The fore margin is fringed by a cartilaginous band and the hind end is loosely attached to the upper surface of the first basibranchial as well as to the inner part of the upper hypobranchial. The shape and the size relative to other bones show certain variations. In *Trachurus japonicus*, *Decapterus lajang*, *D. maruadsi* and *D. akaadsi*, the shape is rodlike and the length is about 7.3 to 4.5 times the greatest width (Fig. 30, A•B•E). In *Naucrates ductor*, broadening forward, the glossohyal is flabelliform, and about as long as wide (Fig. 28, E). In *Chorinemus orientalis* the bone is elongate elliptical in shape, and is about 2.2 times as long as its own greatest width (Fig. 28, F). In other species the shape is generally spatulate. Variations occur also in dentition. *Decapterus russellii*, *Atule djeddaba*, *Atropus atropus*, *Gnathanodon speciosus*, *Selaroides leptolepis* and *Trachinotus bailloni* are entirely toothless. Most of the other species are thickly toothed in an elongate elliptical band extending from the fore margin, or from the middle of the upper surface to the rear end. Especially in *Alectis major* and *Chorinemus*

orientalis, the entire upper surface is thickly toothed (Fig. 28, F; Fig. 29, K).

The urohyal is unpaired, flattened bone, locating just below the ceratohyal, and is surrounded by the muscle of the isthmus. The bone is expanded on its lower border into a pair of lateral wings extending longitudinally. These wings vary in their development according to the species. In *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus*, *Caranx hippos* and *Selaroides leptolepis*, the wings are broad and extend the entire length of the urohyal, the ventral surface of which is in consequence deeply grooved. In *Longirostrum delicatissimus* and *Atule affinis* the wings are well-developed on the posterior half of bone, but undeveloped on the rest (Fig. 30, H•I). *Elagatis bipinnulata* is peculiar in that the urohyal has a medio-ventral longitudinal crest in addition to the pair of broadly expanded lateral wings (Fig. 28, D). In *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Carangoides jordani*, *C. hemigymnostethus*, *Kaiwarinus equula*, *Atropus atropus*, *Alectis ciliaris* and *A. major* the wings are only slightly expanded. In *Alectis ciliaris* the urohyal is provided in the anterior part of the ventral border with a spiniform process projecting downward (Fig. 29, I). Generally speaking, the wings show an obliquely downward inclination, so that a shallow groove is formed on the ventral surface along the midline. In *Atropus atropus* and *Naucrates ductor*, however, the horizontal extension of the wings causes the flattening of the ventral surface. The urohyal is produced at its upper anterior angle forward and upward into a short process in most of the species. In *Trachurus japonicus* and *Trachurops crumenophthalmus* the process is especially long and acute (Fig. 30, A•F), but *Atule djeddaba* and *Selaroides leptolepis* are without any process (Fig. 30, G•K). The urohyal shows a considerable amount of variations in its length relative to other bones. It is slightly longer than, or about as long as the distance from the tip of the hypohyal to the end of the epihyal in *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi* and *D. akaadsi*. The length is larger than, or subequal to the distance from the fore end of the hypohyal to the rear end of the ceratohyal in *Trachurus japonicus*, *Megalaspis cordyla*, *Trachurops crumenophthalmus*, *Atule djeddaba*, *A. affinis*, *Selaroides leptolepis*, *Trachinotus bailloni* and *Naucrates ductor*. In other forms, the urohyal is longer than the ceratohyal, though distinctly shorter than the distance from the tip of the hypohyal to the end of the ceratohyal. Height of the urohyal measured in its hinermost region also extensively. In *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *Trachurops crumenophthalmus*, *Caranx hippos* and *Chorinemus orientalis* the bone is relatively of short statue, the length attaining to 3.3 to 4.7 times the height. In *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Gnathanodon speciosus*, *Alectis ciliaris* and *A. major* the bone is relatively tall, its length not exceeding 0.8 to 1.5 times the height.

The hypohyals are composed of two short bones, arranged dorso-ventrally. They are articulated to the anterior extremity of the ceratohyal, and separated from each other by a narroy cartilage. The dorsal member is produced from the inner surface further inward into a stout process, by which it comes in contact with the corresponding fellow of the opposite side.

The ceratohyal is very large in size, rectangular in shape and, intervening between the epihyal and the hypohyal, constitutes together with the epihyal the major part of the hyoid apparatus. Although the ceratohyal is ordinarily nearly

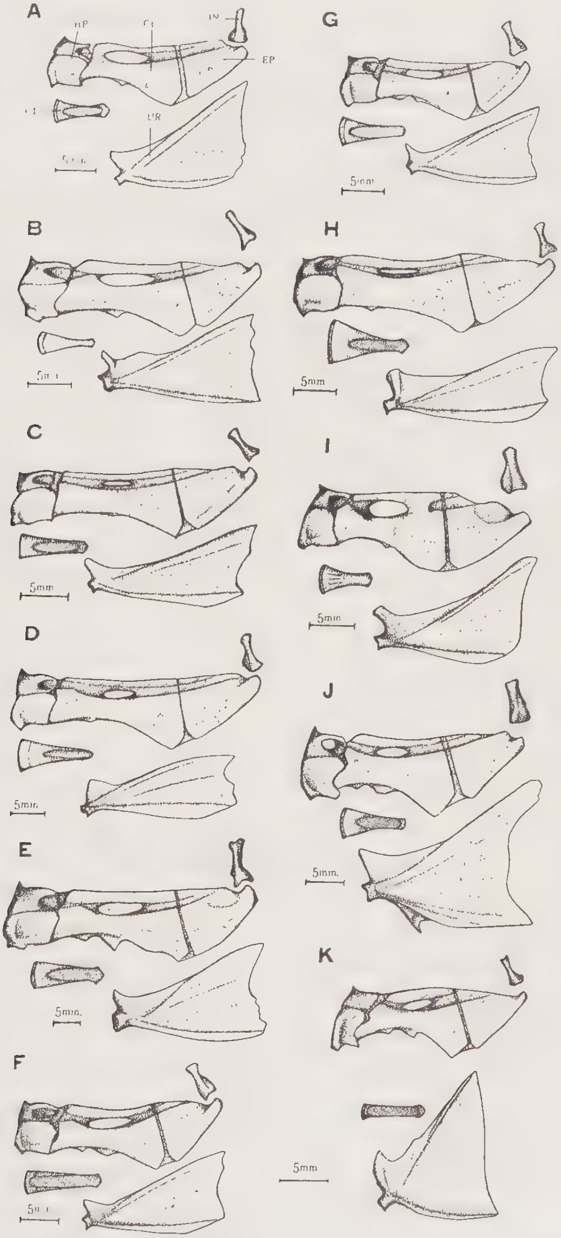

Fig. 29. Outline of the left side of the hyoid apparatus in 11 species. A, *Citula dinema*; B, *Atropus atropus*; C, *Caranx xanthopygus*; D, *C. hippos*; E, *C. ishikawai*; F, *C. melampygus*; G, *C. bixanthopterus*; H, *Melagaspis cordyla*; I, *Gnathanodon speciosus*; J, *Alectis ciliaris*; K, *A. major*.

straight on the upper margin, it is conspicuously raised in its anterior portion in *Citula plumbeus* and *C. malabaricus* (Fig. 30, N·O). Just below the dorsal margin the bone bears a longitudinal groove running parallel with the margin. The groove carries at the middle or somewhat in front a foramen which will be termed the ceratohyal window. The shape of the window is rather variable. In *Megalaspis cordyla*, *Caranx sexfasciatus*, *C. xanthopygus*, *Trachinotus bailloni* and *Chorinemus orientalis* the window is a narrow crevice located at the middle of the channel (Fig. 28, A·F; Fig. 29, C·H). In *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Atule djeddaba* and *A. affinis* it is wider, ovoidal in shape, and situated a little in front of the middle (Fig. 30, B·C·D·E·G·H). *Elagatis bippinulata* has an elongate elliptical window near the fore end of the groove (Fig. 28, D). In other forms, the window is similarly shaped, but found about the middle.

The epihyal is sub-triangular in shape and with bluntly pointed posterior extremity, which carries on the upper side the interhyal. Anterior end is truncate and connected with the ceratohyal by a barrow cartilage. The epihyal bears on the side just below the upper margin a longitudinal groove which continues from the same on the ceratohyal. The groove is nearly straight in most of the species except in *Trachurops crumenophthalmus* and *Naucrates ductor*. In the former of these the dorsal margin is only slightly convex (Fig. 30, F) and in the latter it is strongly and angularly convex, giving the bone a somewhat rhomboidal appearance (Fig. 28, E). The epihyal is thickened in the region of the articular facet which receives the interhyal.

The interhyal is a short rod-like bone, occupying the position highest of all the constituents of hyoid apparatus, which it combines with the hyomandibular as well as with the symplectic through the intervention of a cartilage. It stands vertically and is rather firmly connected at its lowest end with the shallow facet on the upper posterior angle of the epihyal by a ligamental tissue. Varying greatly in its relative size, the interhyal surpasses the half of glossohyal in length in *Trachurops crumenophthalmus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. melampygus*, *C. bixanthopterus*, *C. hippos*, *C. ishikawai*, *Kaiwarinus equula*, *Carangoides jordani*, *C. hemigymnostethus*, *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Atropus atropus*, *Longirostrum delicatissimus*, *Gnathanodon speciosus*, *Selaroides leptolepis*, *Uraspis helvolus*, *Atule djeddaba*, *Alectis ciliaris*, *Trachinotus bailloni*, *Chorinemus orientalis* and *Seriola purpurascens*, but equals to a half of the latter in *Alectis ciliaris*, *Uraspis helvolus* and *Gnathanodon speciosus* (Fig. 29, I·J), and hardly reaches the half in *Trachurus japonicus*, *Megalaspis cordyla*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Atule affinis*, *Alectis major*, *Seriola quinqueradiata*, *Naucrates ductor* and *Elagatis bipinnulata*. In extreme cases, the interhyal does not attain even to one third the length of the glossohyal, as in *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *Seriola quinqueradiata* and *Elagatis bipinnulata* (Fig. 28, B·D; Fig. 30, B·C·D).

Branchiostegal rays are usually seven in number, though eight in *Chorinemus orientalis*. When they are present in seven, five and a half of them are carried by

the ceratohyal and the remaining one and half by the epihyal, but when they are in eight, five are inserted to the ceratohyal and three to the epihyal. They are always ensiform, increasing in length progressively from before backward.

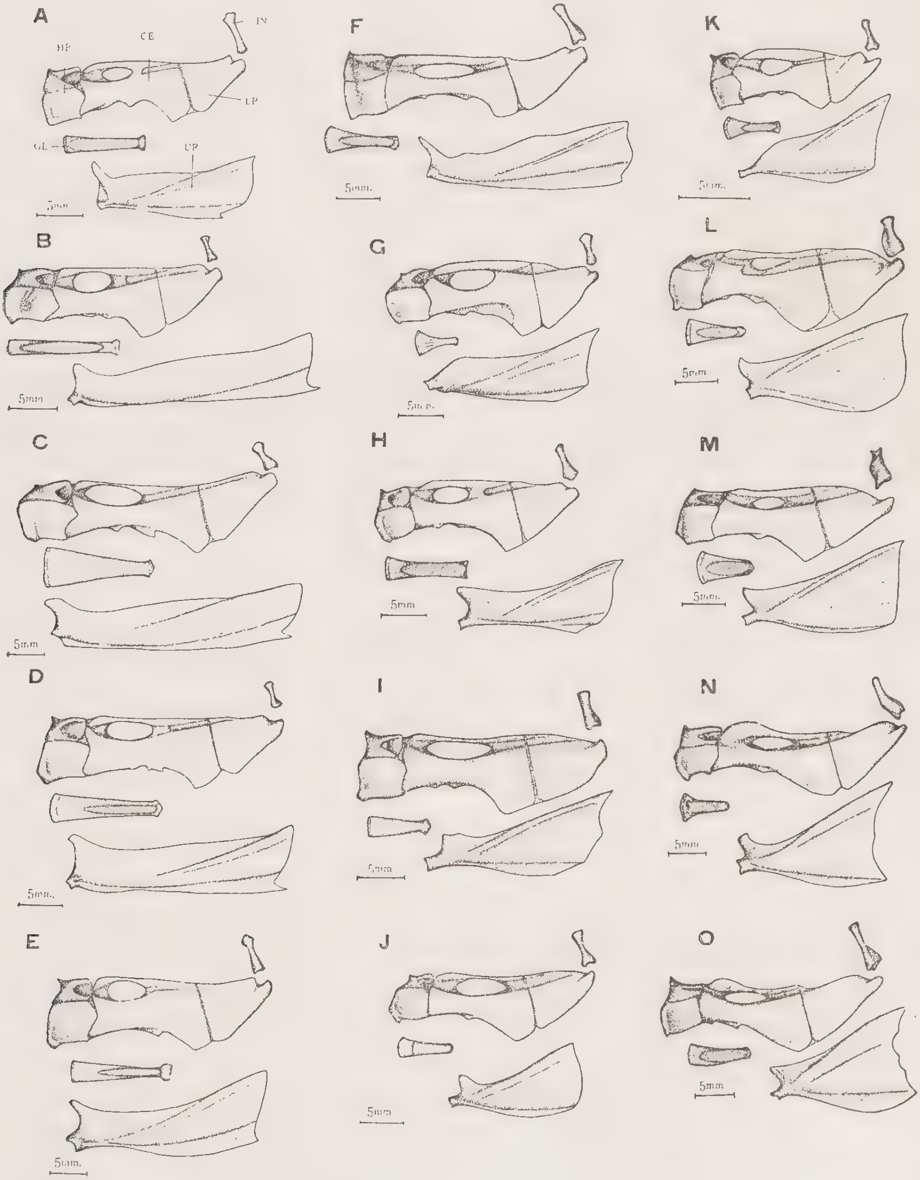

Fig. 30. Outline of the left side of the hyoid apparatus in 15 species. A, *Trachurus japonicus*; B, *Decapterus lajang*; C, *D. russellii*; D, *D. muroadsi*; E, *D. maruadsi*; F, *Trachurops crumenophthalmus*; G, *Atule djeddaba*; H, *A. affinis*; I, *Longirostrum delicatissimus*; J, *Kaiwarinus equula*; K, *Selaroides leptolepis*; L, *Carangoides jordani*; M, *C. hemigymnostethus*; N, *Citula plumbeus*; O, *C. malabaricus*.

Discussion

A. Systematic significance of the hyoid apparatus:

So far as the present author is aware, none of the past authors has given exhaustive account of the characteristics of the hyoid apparatus so as to make a classification of the Carangidae. It appears that the differences in following features, in all probability, meet this purposes: number of branchiostegal rays, constitution of the paired wings of the urohyal, shape of the glossohyal, presence or absence of the glossohyal teeth, relative length of the urohyal, shape of the ceratohyal window, and relative length of the interhyal. The subfamily Chorineminae can be differentiated from other subfamilies found in our waters by having branchiostegal rays eight in number. Genus *Decapterus* is peculiar in the possession of a relatively longer urohyal, which has on the lower margin paired wings more strongly developed than in others. This may be sufficient to separate the genus from others.

B. Consideration on the differentiation of the hyoid apparatus:

Of a number of characters which the hyoid apparatus exhibits, much importance ought to be attached above all things to the number of rays, to the outline of the ceratohyal window and to the relative length of the urohyal. If these points are taken into consideration, the constitution of the apparatus can reasonably be classified into four types, which are indicated in Table 6.

Table 6.
4 types of hyoid apparatus in Japanese Carangidae.

<table>
<tr><th rowspan="2">Type</th><th colspan="3">Characters</th><th rowspan="2">Genera</th></tr>
<tr><th>Number of Branchiostegals</th><th>Ceratohyal window</th><th>Urohyal</th></tr>
<tr><td>1</td><td>8</td><td rowspan="2">somewhat slit-like or elongate ovoidal in shape</td><td rowspan="3">shorter than hyoid body</td><td>Chorinemus</td></tr>
<tr><td>2</td><td rowspan="3">7</td><td>Trachinotus
Seriola
Naucrates
Elagatis
Megalaspis
Caranx
Atropus
Citula
Carangoides
Longirostrum
Gnathanodon
Selaroides
Uraspis
Alectis
Trachurops</td></tr>
<tr><td>3</td><td rowspan="2">wide and ovoidal in shape</td><td>Trachurus
Atule
Kaiwarinus</td></tr>
<tr><td>4</td><td>longer than, or about as long as hyoid body</td><td>Decapterus</td></tr>
</table>

So far as the Carangidae from the Japanese waters are concerned, the hyoid apparatus shows two different patterns in respect of the number of branchiostegal rays. In *Chorinemus* the rays are eight in number, while in others they are seven. Matsubara (1943) states that the rays consisting of a larger number of bones which protect a wider part of the external gill-opening may possibly be considered as more prevailing than those with a smaller number. His hypothesis may be justified by the fact found in primitive teleosts, such as clupeids and salmonids, where the branchiostegal membrane is supported by a large number of rays. If one applies his way of thinking to the present case, *Chorinemus* ought to be regarded as more primitive than others inasmuch as the number of rays is concerned.

The structure of the hyoid apparatus can be classified in another way into two patterns with respect to the shape of the ceratohyal window. In greater part of the genera the window is slit-like or oblong ovate in shape, whereas in *Trachurus*, *Atule*, *Kaiwarinus* and *Decapterus* it is ovoidal. It seems difficult to give a definite conclusion as to which of the two should be regarded as more primitive. Katayama (1959) lays much stress on the configuration of the upper margin of the ceratohyal in deducing the phylogenetical relationships of the serranid fishes on the basis of the hyoid apparatus. He divides the structure of ceratohyal into three distinct types. In the first type, according to him, the ceratohyal has nearly straight upper margin, in the close vicinity of which it has either a parallel groove or an oblong foramen, in the second type the same border is uneven and partly depressed, and in the last type the margin is sinuous throughout entire length. He is of the opinion that the second and third types originate in the degeneration of the narrow isthmus above the groove, or above the foramen of the first type, which consequently represents the most primitive type. In the case of the Carangidae, the isthmus over the ceratohyal window is larger in its width in the form with narrower window than in the form with wider one. It is highly probable that a wider window has resulted from the diminution of the width of isthmus. The form with a wider window may, therefore, be more specialized so far as the matter is concerned with the shape of the ceratohyal window.

The constitution of the hyoid apparatus can be divided again in another way into two patterns, namely on the basis of the length of the urohyal relative to that of the hyoid body. In the majority of cases the urohyal is shorter than the hyoid body, but in the rest, as exemplified by *Decapterus*, it is longer than, or about as long as the hyoid body. As pointed out by Katayama (1959), the urohyal is usually shorter than the hyoid body throughout the percid fishes. A shorter urohyal may, therefore, reasonably be regarded as more primitive.

When we summarize the foregoing consideration, we may reach the conclusion that Type 4 indicated in Table 5 represents the most highly specialized form and 3, 2 and 1 follow in due order (Table 6).

5. Gill-raker

The number and relative lengths of the gill-rakers give another clue for the specific identification. The first branchial arch is generally armed both with gill-rakers and with tubercles. The gill-rakers are the skeletal processes regularly arranged along the anterior margin of the arch. The tubercles are present on the inner surface of the arch throughout its entire length forming a single line, on which they are arranged somewhat irregularly.

The gill-rakers are rather slender, tapering gradually towards the pointed tip. They are longest in the proximity of the bending point of the gill arch, and growing progressively shorter towards both ends. The longest gill-raker is usually a little shorter than, or about as long as the gill-lamella present on the corresponding site. In *Megalaspis cordyla* and *Naucrates ductor* the gill-rakers are much shorter than the gill-lamellae, somewhat claviform. The longest gill-raker in the former is nearly half as long as the corresponding gill-lamella and in the latter 0.7 time as long (Fig. 31, C; Fig. 32, L). Generally speaking, the inner surface of the gill-raker is thickly armed with short, numerous prickles. In *Atule djeddaba* alone these prickles are elongate and present in a much smaller number (Fig. 33, R). Gill-rakers on the first branchial arch extensively vary in their number. Roughly speak-

Fig. 31. Back side of the first gill arch in 6 species, especially showing the gill-raker and main tubercle. A, *Seriola purpurascens*; B, *S. quinqueradiata*; C, *Naucrates ductor*; D, *Caranx ishikawai*; E, *Uraspis helvolus*; F, *Chorinemus orientalis*.

ing, *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi* and *D. akaadsi* possess a large number of gill-rakers than *Caranx hippos*, *Uraspis helvolus* and *Naucrates ductor*. Where there is a certain variablity even within a species, it may be wise to look forward until the examination of a sufficient number of specimens enables us to establish a specific separation on the basis of the number of gill-rakers.

Table 7.
Number of gill-rakers in representative species.

Number of gill-rakers on first arch	Species
55—45	*Trachurus japonicus*, *Decapterus macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*
45—40	*D. russellii*
40—35	*Trachurops crumenophthalmus*, *Citula malabaricus*, *Longirostrum delicatissimus*, *Atule affinis*, *Selaroides leptolepis*
35—30	*Carangoides jordani*
30—25	*Megalaspis cordyla*, *Citula dinema*, *Kaiwarinus equula*, *Carangoides hemigymnostethus*, *Caranx melampygus*, *C, bixanthopterus*, *C, ishikawai*, *Atropus atropus*, *Gnathanodon speciosus*, *Seriola quinqueradiata*
25—20	*Citula plumbeus*, *Caranx xanthopygus*, *C. sexfasciatus*, *Alectis ciliaris*, *Trachinotus bailloni*, *Seriola purpurascens*, *Chorinemus orientalis*
20—15	*Caranx hippos*, *Uraspis helvolus*, *Naucrates ductor*

When viewed from the inner side, the first branchial arch has numerous tubercles arranged in a single regular row extending throughout the entire length of the anterior margin. The tubercle which will be called the main tubercle is usually armed with a variable number of prickles. In addition to the main tubercle, smaller ones with poorly developed prickles are frequently found between every two of adjoining gill-rakers or between main tubercles. These smaller ones will conveniently be called the accessory tubercles. With respect to the main tubercles there are some specific variations in their general shape and in the development of prickles. In accordance with the constitution of these tubercles the Japanese Carangidae can be divided into several types. In the first type which comprises the species other than the sixteen named below, each of the main tubercle is highly raised to form a ridge or a disk, and thickly covered with more or less equal-sized prickles. In the second type which is represented by *Longirostrum delicatissimus*, the tubercle is similar to that of the first type in shape, but is different in being densely granuated on its surface instead of being thorny (Fig. 33, P). The thire type, for which *Atule djeddaba* stands, has a similar-shaped tubercle which is sparsely covered by acuminating prickles (Fig. 33, R). The fourth type, the sole representative of which is *Uraspis helvolus*, has each tubercle strongly protruded, wart-like in appearance,

and scarcely covered with prickles except at the top, which is crowded with stouter ones (Fig. 31, E). In the fifth type, that is, in *Atropus atropus* the tubercle is produced into a prominent wart in the middle of its anterior side, and is thickly coated with stouter prickles in this wart, but with sparser very minute ones in the rest portion (Fig. 32, J). In the sixth type which includes *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai* and *Citula dinema*, the tubercle is slightly bulged about the middle of the anterior side and is armed with several longer, stouter, anteriorly projecting prickles on this bulge, though with tiny prickles in the rest portion (Fig. 31, D). In the seventh type which is exemplified by *Citula plumbeus*, *C. malabaricus*, *Alectis ciliaris*, *A. major* and *Chorinemus orientalis*, the tubercle is scarcely bulged and the prickles covering the middle of the anterior side are only slightly stouter than those of the other part (Fig. 31, F; Fig. 32, G·H·I). In the last type, to which *Seriola purpurascens* belongs, the main tubercle is flattened, irregular in shape, and sporadically scattering on the inner side of the arch (Fig. 31, A). The main tubercle is thus indistinguishable from the accessory one in this species.

Number of main tubercles on the first arch considerably varies with species (Table 8). There is a tendency that their number is roughly proportional to the

Fig. 32. Back side of the first gill arch in 6 species, especially showing the gill-raker and main tubercle. G, *Alectis ciliaris*; H, *Citula plumbeus*; I, *C. malabaricus*; J, *Atropus atropus*; K, *Citula dinema*; L, *Megalaspis cordyla.*

Fig. 33. Back side of the first gill arch in 6 species, especially showing the gill-raker and main tubercle. M, *Decapterus lajang*; N, *D. maruadsi*; O, *D. muroadsi*; P, *Longirostrum delicatissimus*; Q, *Citula hemigymnostethus*; R, *Atule djeddaba.*

Table 8.
Number of main tubercles in representative species.

Number of main tubercles on the first arch	Species
35—30	*Trachurus japonicus, Decapterus maruadsi*
30—25	*Decapterus macrosoma, D. muroadsi, D. lajang, D. russellii, Longirostrum delicatissimus, Atule affinis, Selaroides leptolepis, Alectis ciliaris, A. major, Chorinemus orientalis*
25—20	*Megalaspis cordyla, Trachurops crumenophthalmus, Kaiwarinus equula, Carangoides jordani, C. hemigymnostethus, Caranx hippos, C. melampygus, C. bixanthopterus, C. ishikawai, Seriola quinqueradiata*
20—15	*Citula plumbeus, C. dinema, C. malabaricus Caranx xanthopygus, C. sexfasciatus, Atropus atropus, Atule djeddaba*
15—10	*Uraspis helvolus, Naucrates ductor*

number of gill-rakers. As to this point, however, a confirmation based on the ample material is necessary.

Discussion

The gill-rakers are the bony structure having developed for the prevention of dangers of injuries which food fragments introduced into branchial cavity may inflict upon gill-lamellae. They are longer and more numerous in good swimmers which feed on smaller organismus. Accordingly, largeness or smallness in the number of gill-rakers in the Carangidae may have a certain relation to their feeding habits and the swiftness of their movement. Gill-rakers are larger in their number in *Decapterus* and *Trachurus* which move more quickly and feed on finer food animals, but in a smaller number in *Alectis*, *Uraspis*, *Gnathanodon*, *Citula* and *Caranx*, all of which are high and compressed in their statue and less active swimmers.

Although nothing certain has hitherto been known, role of main tubercles appear to lie in assisting the function of gill-rakers; that is, being pressed against the gill-rakers on the second branchial arch, they filter the water passing from the pharynx into the gill cavity and prevent the intrusion of solid material. It is natural, therefore, than the development of the main tubercle is almost parallel with that of gill-rakers.

At any rate, numbers and development of these bony appendices in the Carangidae may be proportional to the feeding habits and the swimming activities.

6. Orbital bones

The taxonomy of such fishes as Scorpaenicae (Matsubara, 1943), Platycephalidae (Matsubara and Ochiai, 1955) and Serranidae (Katayama, 1959) has attached much importance to the orbital bones in conjecturing the phylogenetical relationships among genera, subfamilies and families. Although Starks (1911) gave a brief description on the orbital bones of the Carangidae our knowledge on these remains incomplete and unsatisfactory. In the following paragraphs it is intended to deduce some probable phylogenetical relationships among genera from the configuration of the orbital bones, which are, in turn, subservient to the taxonomy of the family.

The orbital bones consist of one preorbital and five suborbital bones. The preorbital bone, which is invariably larger than any of the suborbital bones, is ovoidal, quadrangular, rhombic, or triangular in shape. On the upper side there is usually a well-developed nodule by which the bone is connected with the ectethmoid. The dorsal half of the bone, in which the sensory canals are contained, is relatively smooth on surface and thin in thickness in most of the species. In *Trachinotus bailloni*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagatis bipinnulata* and *Chorinemus orientalis*, however, this is somewhat thickened and so rugose that the radiating sensory canals become indistinct (Fig. 34, A·B·C·D). The constitution of the bone can be assorted into three distinct types in accordance wish the extent of the outward curvature of the surface. In the first type, as represented by *Trachurus*

japonicus, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. akaadsi*, *Trachurops crumenophthalmus* and *Selaroides leptolepis*, the surface is strongly bulged outward. In

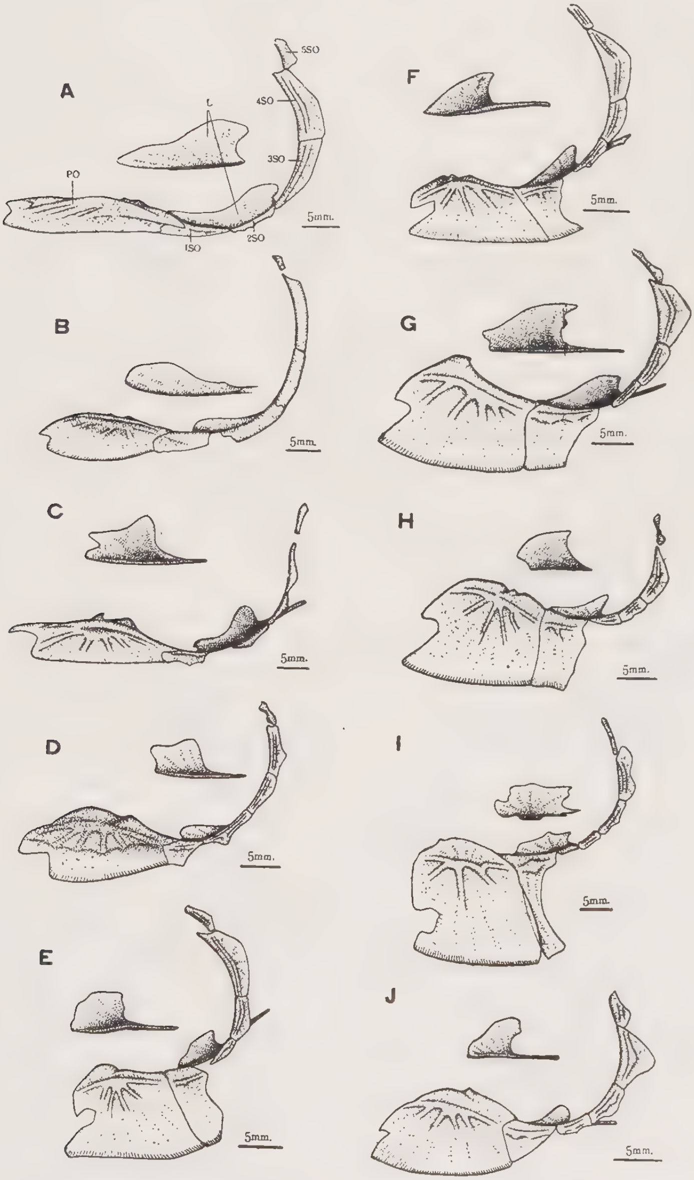

Fig. 34. Outline of the left side of the suborbital bones in 10 species. PO, preorbital; 1SO, first suborbital; 2SO, second suborbital; 3SO, third suborbital; 4SO, fourth suborbital; 5SO, fifth suborbital; L, suborbital shelf (A, B, C, D,) suborbital lamina (E, F, G, H, I, J). A, *Elagatis bipinnulata*; B, *Naucrates ductor*; C, *Seriola quinqueradiata*; D, *S. purpurascens*; E, *Citula plumbeus*; F, *Atropus atropus*; G, *Carangoides jordani*; H, *Gnathanodon speciosus*; I, *Alectis ciliaris*; J, *Longirostrum delicatissimus*.

the second type which comprises *Megalaspis cordyla*, *Atule djeddaba*, *A. affinis*, *Trachinotus bailloni*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagatis bipinnulata* and *Chorinemus orientalis* the surface is slightly bulged. In the last type which includes the rest species the surface is completely flattened and much larger in area. In all cases the anterior border of the bone invariably bears a V-shaped notch in contrast to the posterior border which diverges in its outline in establishing contact with the first suborbital bone. The latter border is deeply notched in *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Seriola quinqueradiata*, *S. purpurascens* and *Elagatis bipinnulata*, but rather shallowly in *Trachurops crumenophthalmus*, *Selaroides leptolepis* and *Naucrates ductor*, and almost straight, lacking in notch, in *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Carangoides jordani*, *C. hemigymnostethus*, *Kaiwarinus equula*, *Longirostrum delicatissimus*, *Atropus atropus*, *Gnathanodon speciosus*, *Uraspis helvolus*, *Alectis ciliaris* and *A. major*. In every case, the line of contact between the preorbital and the first suborbital extends for some lengths. In *Trachinotus bailloni* and *Chorinemus orientalis* the posterior border of the preorbital is produced backward, so that this bone keeps in touch with the first suborbital only by a short line. The ratio between length and width of the preorbital varies according to the species. The ratio is 4.0 to 3.0 in *Elagatis bipinnulata* and *Chorinemus orientalis*, 2.8 in *Seriola quinqueradiata*, 2.4 to 2.2 in *Trachinotus bailloni* and *Naucrates ductor*, 2.0 to 1.9 in *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Megalaspis cordyla*, *Atropus atropus* and *Atule affinis*, 1.9 to 1.5 in *Trachurops crumenophthalmus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *Kaiwarinus equula*, *Longirostrum delicatissimus*, *Selaroides leptolepis*, *Atule djeddaba* and *Seriola purpurascens*, 1.5 to 1.0 in *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Carangoides jordani*, *C. hemigymnostethus*, *Caranx melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Gnathanodon speciosus* and *Alectis ciliaris*, and 0.5 in *Alectis major*. The first suborbital bone is interposed between the preorbital and the second suborbital, and is rectangular, triangular, rhombic, ovate or rod-like in shape. This bone is narrower than long in *Trachurus japonicus*, *Megalaspis cordyla*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus*, *Atule djeddaba*, *A. affinis*, *Atropus atropus*, *Selaroides leptolepis*, *Longirostrum delicatissimus*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagatis bipinnulata*, *Trachinotus bailloni* and *Chorinemus orientalis*, whereas wider than in the rest species. The second suborbital is much smaller than the first suborbital. The third suborbital can be classified into two types in accordance with its shape. In one type which is represented by *Megalaspis cordyla*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Atule affinis*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus* and *C. ishikawai*, the bone is wider posteriorly than anteriorly and less than twice as wide as long, whereas in the second type to which rest of the species belongs it is wider than twice the length. The fourth suborbital comes next to the preorbital bone in size. As in the preceding one, the fourth bone is broader posteriorly showing a triangular or quadrangular shape in *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*,

D. akaadsi, *Trachurops crumenophthalmus*, *Carangoides jordani*, *C. hemigymnostethus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Citula dinema*, *Longirostrum delicatissimus* and *Atule affinis*. In other species, however, it is narrow and elongate. The fifth suborbital lying above the sphenotic is usually smaller than either the second suborbital or the third.

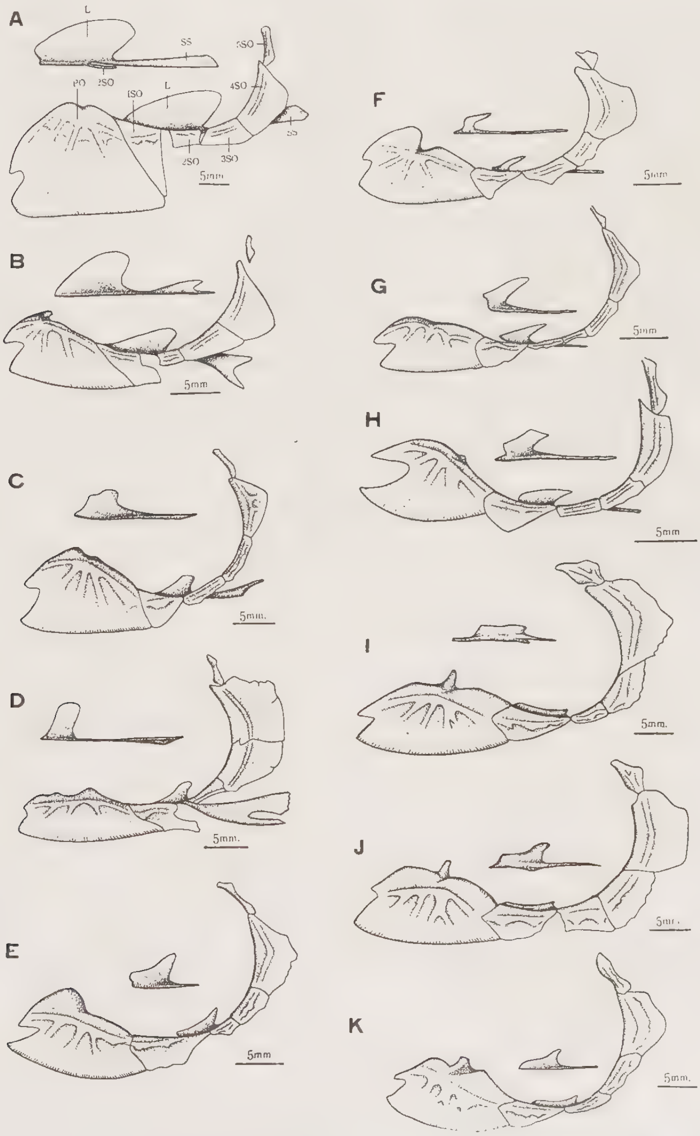

Fig. 35. Outline of the left side of the suborbital bones in 11 species. A, *Caranx ishikawai*; B, *C. xanthopygus*; C, *Kaiwarinus equula*; D, *Megalaspis cordyla*; E, *Trachurops crumenophthalmus*; F, *Atule affinis*; G, *Atule djeddaba*; H, *Selaroides leptolepis*; I, *Decapterus muroadsi*; J, *D. maruadsi*; K, *Trachurus japonicus*.

The structural constitution of orbital bones are referable to two types in the Carangidae, one being characterized by the possession of suborbital shelf inwardly projecting from the upper border of the second or third suborbital bone, and the other by having a lamellar bone, which retains merely a narrow connection with the second suborbital, though resembling, at first sight, the suborbital shelf. This lamellar bone in the second type will be named the suborbital lamina. The first type is found in *Chorinemus orientalis*, *Trachinotus bailloni*, *Elagatis bipinnulata*, *Naucrates ductor*, *Seriola quinqueradiata* and *S. purpurascens*. In the first two of these species the suborbital shelf is nearly circular in shape without pointing backward. In the succeeding two it is of elongate ovoidal shape acuminating backward (Fig. 34, A•B). In the last two the suborbital shelf is wider in area and furnished with a sharp process, suborbital process, extending posteriorly along the outer side of the shelf (Fig. 34, C. D). Other species for the greater part belong to the type with the suborbital lamina, which comes in contact either with the first suborbital, or with the second in addition. All the genera other than *Decapterus*, *Selaroides* and *Atule* belong to the latter case, whereas these three to the former case (Fig. 35, F•G•H•I•J). Ample of varities are found in the development of the suborbital process as well as in the shape of the suborbital lamina. In the first type which includes *Trachurops crumenophthalmus*, *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Carangoides jordani*, *C. hemigymnostethus*, *Alectis ciliaris* and *A. major*, the suborbital lamina is greatly expanded, twice as long as wide or a little shorter, and the suborbital process is rod-like in shape. The second type comprising *Uraspis helvolus* and *Gnathanodon speciosus* is similar to the preceding in the general appearance of the lamina, but is without suborbital process (Fig. 34, H). The third type which is represented by *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai* and *Kaiwarinus equula*, has the lamina widely expanded, less than twice as wide, and the long, ensiform stout process which is compressed on the plane perpendicular to the lamina (Fig. 35, A•B•C). The fourth type to which *Megalaspis cordyla* belongs, has a small quadrangular lamina, which is slightly wider than long and the process similar to that of the preceding type, but fragile (Fig. 35, D). The fifth type which contains *Atule djeddaba*, *A. affinis* and *Selaroides leptolepis* has the elongate, aciform process and the lamina much reduced in size and wider than long (Fig. 35, F•G•N). The sixth type, involving *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi* and *D. akaadsi*, possesses a small narrow lamina besides the aciform process (Fig. 35, I•J•K).

Discussion

Interrelations among the various forms of orbital bones in the Carangidae will be considered from the phylogenetical point of view. In such a speculation the followings appear to belong to the points particularly worthy of note: presence either of suborbital shelf or of suborbital lamina, general shape of the suborbital

process and the extent of its elongation, developmental degree and configuration of the suborbital lamina and kinds of suborbital bones with which the suborbital lamina comes in touch.

As stated before, the Japanese carangid fishes may be grouped into two major types according to the form of the shelf-like process of the suborbital bone. Type 1, comprising *Chorinemus*, *Trachinotus*, *Elagatis*, *Naucrates* and *Seriola*, is furnished with the suborbital shelf in contrast to Type 2 which includes all other genera carrying the suborbital lamina. It appears probable that the suborbital lamina originates in the reduction of the connection between the orbital bone and the suborbital shelf. If such is the case, it may be reasonable to consider Type 1 as more primitive than Type 2. Type 1 is further divisible into two sub-types. *Chorinemus*, *Trachinotus*, *Elagatis* and *Naucrates* all of which belong to Sub-type 1 are entirely lacking in the suborbital process and Seriola, the sole representative of Sub-type 2, carries sharply projecting one. In Type 2 the differentiation is so much diversified as to yield six sub-types (Table 9). Sub-type 1, as represented by *Citula*, *Atropus*, *Alectis*, *Carangoides*, *Longirostrum* and *Trachurops*, is presumably most prevailing in Type 2. Characteristics of this sub-type consist in that the suborbital lamina is in contact with

Table 9.
6 sub-types of the suborbital lamina in Japanese Carangidae (Type 2).

<table>
<tr><th rowspan="2">Sub-type</th><th colspan="3">Characters</th><th rowspan="2">Genera</th></tr>
<tr><th>Suborbital lamina</th><th>Development of lamina</th><th>Suborbital process</th></tr>
<tr><td>1</td><td rowspan="5">in contact with first two suborbital bones</td><td rowspan="3">widely expanded</td><td>well-developed and rod-shaped</td><td>Citula
Atropus
Alectis
Carangoides
Longirostrum
Trachurops</td></tr>
<tr><td>2</td><td>absent</td><td>Uraspis
Gnathanodon</td></tr>
<tr><td>3</td><td rowspan="2">well-developed and ensiform</td><td>Caranx
Kaiwarinus</td></tr>
<tr><td>4</td><td rowspan="3">small in size</td><td>Megalaspis</td></tr>
<tr><td>5</td><td rowspan="2">well-developed and rod-shaped</td><td>Trachurus</td></tr>
<tr><td>6</td><td>in contact with first suborbital bone</td><td>Selaroides
Atule
Decapterus</td></tr>
</table>

the inner side of the first two suborbital bones at their upper border, in the broadness of the lamina and in the suborbital process not being ensiform, but well-developed. Sub-type 2, including *Uraspis* and *Gnathanodon*, closely resembles the preceding sub-type in the general appearance of the lamina, but differs in having no suborbital process. It is far from unlikely that Sub-type 2 originates in the disappearance of the suborbital process of Sub-type 1. In Sub-type 3, which is repre-

sented by *Caranx* and *Kaiwarinus*, the lamina is similar to that of those sub-types in the general form, but the suborbital process is compressed on a plane vertical to the lamina in the shape a razor. Sub-type 4, as represented by *Megalaspis*, bears a certain resemblance to Sub-type 3 in the possession of ensiform process, but in the lamina being fragile and much reduced in size. Sub-type 5 which involves *Trachurus* is allied to Sub-type 1 in the shape of the suborbital lamina which, however, is much smaller in size. Sub-type 6, which includes *Selaroides*, *Atule* and *Decapterus*, is peculiar in having the characters undiscoverable in any other genera, and the suborbital lamina which is much reduced in size is contact with the inner side of the upper margin of the first suborbital bone. It appears, therefore, that Sub-type 6 is more specialized than the rest sub-types.

7. Shoulder girdle

Of 21 representative species of the Carangidae, with whose shoulder girdles Starks (1911) dealt, *Elagatis bipinnulata*, *Naucrates ductor*, *Trachurops crumenophthalmus*, *Megalaspis cordyla*, *Gnathanodon speciosus* and *Alectis ciliaris* are known to our waters. His study is undoubtedly valuable, yet our knowledge on this girdle is not comprehensive.

Under these circumstances the author is intending to disclose the features of this girdle in order to utilize the gained knowledge for classifying genera and subfamilies, or species, and in finding probable relationships among these.

The shoulder girdle is composed of seven constituents: posttemporal, supraclavicle, clavicle, hypercoracoid, hypocoracoid, actinost and postclavicle. There is little fundamental difference among the members of this family as regards the general arrangement of these bones.

The posttemporal occupying its position at the highest level of the shoulder girdle suspends all other elements. At the fore end the bone is deeply bifurcate. The dorsal branch resulted from bifurcation extends forward and upward, and is firmly fixed to the epiotic by a ligamental tissue. The ventral branch extends forward and downward so as to join the posterior edge of the opisthotic. In *Chorinemus orientalis*, however, the branch is attached to the upper surface of the opisthotic. This is usually the case with Scombridae as pointed by Starks (1911). The dorsal branch is ordinarily longer than the ventral one. In *Trachinotus bailloni* the latter is much reduced in size remaining to extend beyond the main portion of the bone only for a short distance (Fig. 37, A). Besides, the posttemporal of this species makes an articulation to the opisthotic ranging for unusually large distance. Near the junction of the two branches there is usually a wart-like, forwardly bulging protuberance, at the top of which the opening of the sensory canal is located. In *Naucrates ductor* and *Seriola quinqueradiata*, the protuberance is far prominent (Fig. 36, C·D). The height of the bone relative to its length greatly varies. For convenience' sake, the height is represented by the shortest distance from the anteriormost of

Fig. 36. Outline of the left side of the shoulder girdle in four species. CL, clavicle; HOC, hypocoracoid; HRC, hypercoracoid; PC, postclavicle; PTM, posttemporal; SC, supraclavicle. A, *Elagatis bipinnulata*; B, *Seriola purpurascens*; C, *S. quinqueradiata*; D, *Naucrates ductor*.

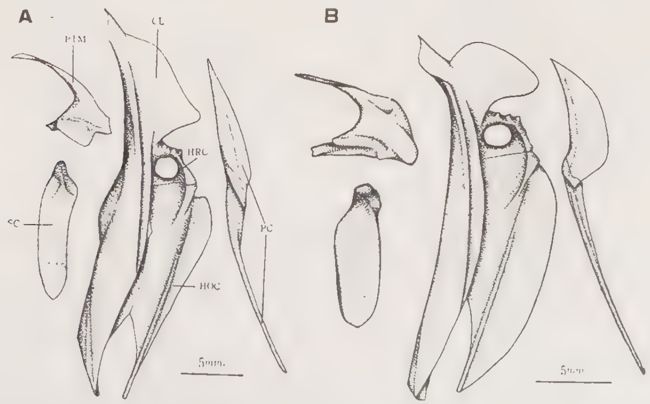

Fig. 37. Outline of the left side of the shoulder girdle in 2 species. A, *Trachinotus bailloni*; B, *Chorinemus orientalis*.

the lower branch to the dorsal margin of the upper branch, and the length is taken from the anteriormost of the upper branch to the posteriormost of the bone. In *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Megalaspis cordyla*, *Trachurops crumenophthalmus*, *Atule djeddaba*, *A. affinis*, *Selaroides leptolepis*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor* and *Elagatis bipinnulata* the bone is relatively short in height, being less than half as high as long. In *Decapterus lajang* it is especially short in height and length to height is 3.9 (Fig. 43, C). In other species the height is larger than a half of the length. In extreme case as in *Citula malabaricus* the height is subequal to the length (Fig. 44).

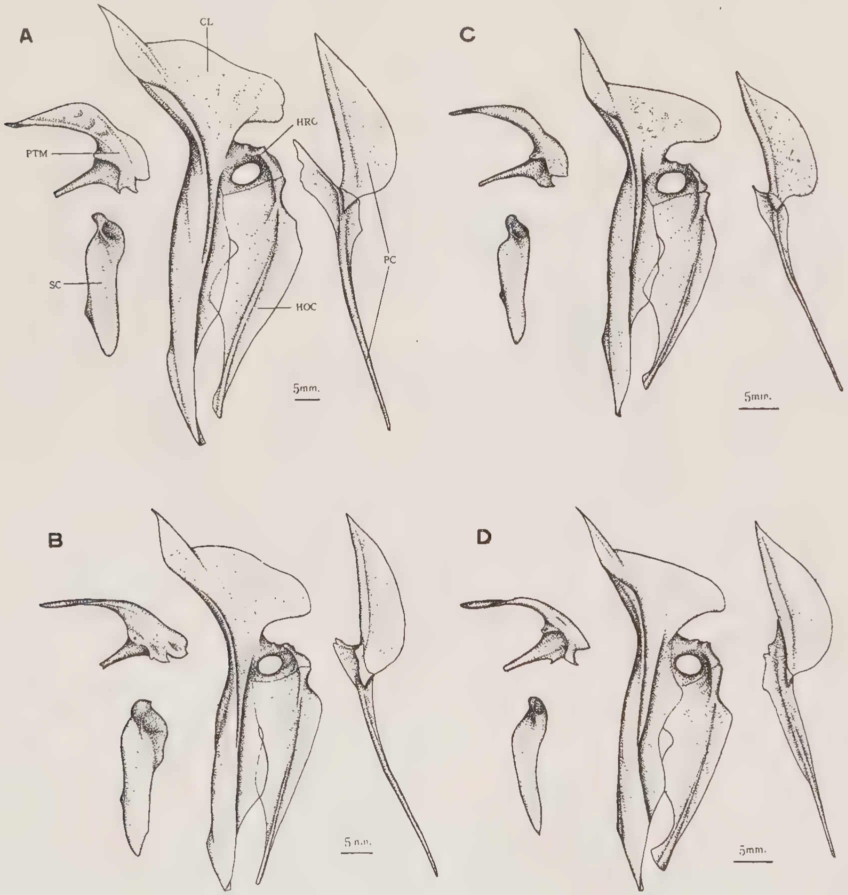

Fig. 38. Outline of the left side of the shoulder girdle in 4 species. A, *Caranx ishikawai*; B, *C. hippos*; C, *C. melampygus*; D, *Citula dinema*.

The supraclavicle is a flat, oval bone, simple in structure and extending from the ventro-posterior angle of the posttemporal to the upper portion of the clavicle. A strong ligament, called the clavicular ligament, is attached to the upper part of the supraclavicle on its inner surface covering a broad area. The bone is usually longer than wide, but its general form somewhat varies. In *Trachurus japonicus*,

Trachurops crumenophthalmus and *Alectis major*, it is more or less slenderly elongated, being less than one fifth as wide as long (Fig. 40, B; Fig. 41, D; Fig. 42, C). A conspicuous disc-like expansion with rounded margin is present at about the middle of the anterior side of the bone in *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus* and *Selaroides leptolepis* (Fig. 41, C·D; Fig. 42; Fig. 43). In others this expansion is inconspicuous.

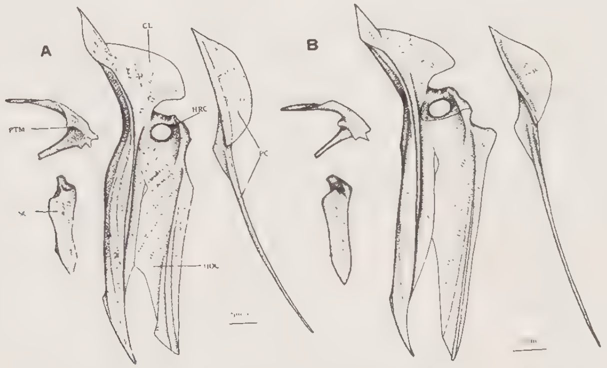

Fig. 39. Outline of the left side of the shoulder girdle in 2 species. A, *Citula plumbeus*; B, *Atropus atropus*.

The clavicle is a large curved bone rather complicated in strucure and giving a support for the lower portion of the shoulder girdle. The upper region of the clavicle is widely expanded and flattened into a somewhat wing-like plate. The upper anterior corner of that region bears a sharp, stout dorso-anteriorly directed process which is attached to the inner surface of the supraclavicle. The lower end is attenuating to a narrow point. The main portion of the bone is composed of two shelves, the external and internal, which meet each other to form an anterior ridge. The two shelves make approximately a right angle between each other, and

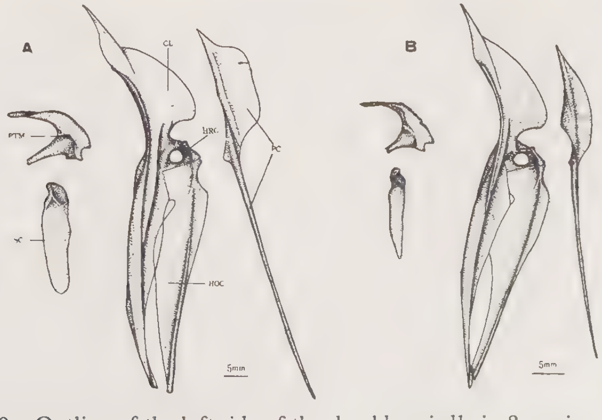

Fig. 40. Outline of the left side of the shoulder girdle in 2 species. A, *Alectis ciliaris*; B, *A. major*.

when viewed from the side, a broad posterior marginal area of the internal shelf is exposed. Among the species exhibiting such a character, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagatis bipinnulata* and *Chorinemus orientalis* are peculiar in having a wide external shelf, which covers for greater part of the internal shelf (Fig. 36; Fig. 37, B). In *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi* and *D. akaadsi*, however, the greatly enlarged external shelf meets internal one at an acute angle and conceals the latter for the most part in lateral aspect (Fig. 43). At times, the external shelf is expanded along the anterior margin into another inwardly turning shelf which will be termed anterior shelf. Development of this shelf also greatly varies. In *Naucrates ductor* the shelf is wide and, showing the inclination same as the external shelf in relation to the internal one, occupies about three-quarters of the entire length of the bone (Fig. 36, D). Although somewhat poor in development, the anterior shelf is conspicuous also in *Trachurus japonicus*, *Megalaspis cordyla*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Carangoides jordani*, *C. hemigymnostethus*, *Longirostrum delicatissimus*, *Selaroides leptolepis*, *Atule djeddaba*, *A. affinis* and *Elagatis bipinnulata*.

The hypercoracoid is a small, flat bone situating below and behind the posterior corner of the clavicle. It is articulated to the hypocoracoid with a straight suture extending entire ventral border and to the internal shelf of the clavicle with the lower half of the anterior border. The upper and anterior half of the bone lies upon the clavicle to which it is firmly attached. The bone is pierced by a large, round, or oval foramen at about the center. The upper and posterior margin of the bone is much thickened and bears three condyles, the first of which is fixed to the base of the first pectoral ray and the rest of which is to the actinosts. Since the general form of the bone varies according to the species, its length relative to the same of the hypocoracoid is taken in order to make a comparison of its size. For convenience' sake, the length of the hypercoracoid is represented by the calibre measured on the anterior margin, and the same of the hypocoracoid by the distance from the posterior end of the upper articulating border to the lower end of this bone. The ratio of the latter to the former is 6.0 in *Atropus atropus*, *Alectis ciliaris* and *A. major*, 5.3 to 4.5 in *Citula plumbeus*, *Uraspis helvolus*, *Seriola quinqueradiata*, *Naucrates ductor* and *Chorinemus orientalis* and 4.0 to 3.2 in others.

The hypocoracoid is a thin falciform bone giving a chief support for the lower part of the shoulder girdle. It is articulated to the hypercoracoid dorsally and to the internal shelf of the clavicle anteriorly. The ventro-anterior end of the bone is elongated into a slender rod in most of the species except in *Citula plumbeus*, *D. malabaricus*, *Atropus atropus* and *Chorinemus orientalis*, where the elongation is much larger in width (Fig. 37, B; Fig. 39; Fig. 44). Between the hypocoracoid and the clavicle there is a large deep sinus which was named interosseous space by Starks (1930) and Matsubara (1943). As to the form of the upper-posterior margin of the bone two types are distinguishable. In the first type involving *Seriola quinqueradiata*, *S. purpurascens*, *Elagatis bipinnulata* and *Naucrates ductor*, the dorso-posterior angle

of the bone is strongly produced into an angular process, the postcoracoid process. In the first three of these species the process is spatulate, whereas in the last it is triangular (Fig. 36, A·B·C·D). The second type comprising all others has the postcoracoid process undeveloped.

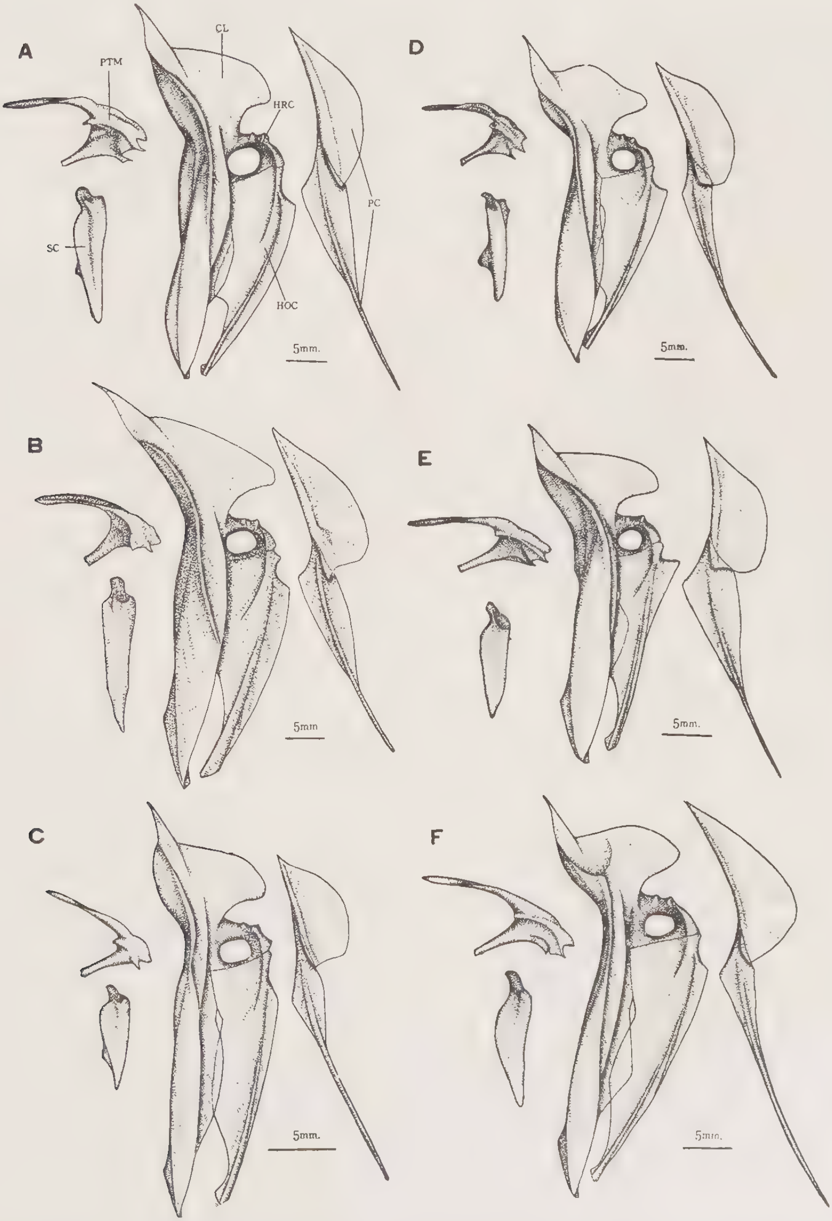

Fig. 41. Outline of the left side of the shoulder girdle in 6 species. A, *Longirostrum delicatissimus*; B, *Gnathanodon speciosus*; C, *Selaroides leptolepis*; D, *Trachurus japonicus*; E, *Atule affinis*; F, *A. djeddaba*.

The postclavicle is composed of dorsal and ventral elements. The head of the ventral element is buried under the lower end of the dorsal element to which it is

Fig. 42. Outline of the left side of the shoulder girdle in 6 species. A, *Carangoides jordani*; B, *Uraspis helvolus*; C, *Trachurops crumenophthalmus*; D, *Carangoides hemigymnostethus*; E, *Kaiwarinus equula*; F, *Megalaspis cordyla*.

Fig. 43. Outline of the left side of the shoulder girdle in 4 species. A, *Decapterus russellii*; B, *D. muroadsi*; C, *D. lajang*; D, *D. maruadsi*.

firmly attached. The dorsal constituent is always longer than wide in all cases, but variable both in size and in shape. In most of the species it is expanded into a thin lamella and is usually wider than the supraclavicle. In *Trachinotus bailloni*, however, it is so much narrowed as to be narrower than the supraclavicle (Fig. 37, A). The ventral constituent of the bone is elongated into a slender postero-ventrally directing aciculum. It is also rather variable in form. In *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor* and *Elagatis bipinnulata*, it gradually tapers towards the apex and, having a relatively large width, is neither aciform nor rib-like in form (Fig. 36). In other species, however, it exhibits an aciform, or rib-like appearance in its entire length, or, at least, in its lower half. In *Citula malabaricus*, *C. plumbeus*, *Atropus atropus*, *Alectis ciliaris* and *A. major* the entire bone resembles either a needle or a rib (Fig. 39; Fig. 40).

The actinosts are present in four and rod-like in shape. The suture between the hypercoracoid and hypocoracoid usually ends in the region between the third

and fourth actinosts, but the ending, at times, lies in various points in the region ranging from the middle of the third to the middle of the fourth, so that two and a half to three and a half of actinosts are supported by the hypercoracoid.

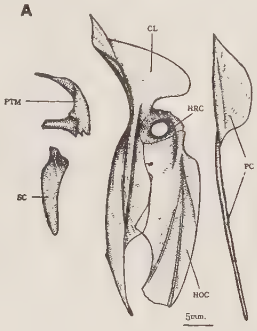

Fig. 44. Outline of the left side of the shoulder girdle in *Citula malabaricus*.

Discussion

A. Systematic significance of the shoulder girdle:

Comparative study of the shoulder girdle made above results in disclosing the features valuable for the taxonomy of the Carangidae, especially for defining the genera and subfamilies. These are: articulation of the ventral branch of the posttemporal to the opisthotic, extent of the elongation of the ventral branch of the posttemporal, relative height of the posttemporal, general form of the supraclavicle, relative width of the external shelf of the clavicle, the angle which the external and internal shelves of the clavicle make, development of the anterior shelf of the clavicle, presence or absence of the postcoracoid process, relative size of the hypercoracoid, and size and form of the postclavicle. Some of the remarkable example showing the usefulness of the shoulder girdle for the taxonomy will be demonstrated below. Trachinotinae is sharply distinguishable from other subfamilies of the Carangidae by having the ventral branch of the posttemporal much reduced in length and only slightly projecting from the principal part of this bone, which is attached to the opisthotic with a broad area. Possession of the well-developed postcoracoid process on the hypocoracoid, which is separated from the lowest actinost by a deep notch, and of the ventral element of postclavicle gradually narrowing towards the end in a rib-like are met with only in Naucratinae and such will be subservient for the distinction of this subfamily from others. *Decapterus* is unique in the external shelf of the clavicle being widely expanded so as to make an acute angle with the internal one, and in the internal shelf of the clavicle largely concealed by the posterior extension of the external one. These may thus provide us with the important characteristics in defining this genera.

B. Consideration on the differentiation of the shoulder girdle:

The conclusion to be deduced from the detailed examination lies in that the essential features of the shoulder girdle can be assorted into 2 types and 3 sub-types shown in Table 9.

The features essential for the right understanding of the phylogeny are: length of the ventral branch of the posttemporal, articulation of the posttemporal to the opisthotic, relative width and form of the dorsal element of the postclavicle, angle interposed between the external and the internal shelves of the clavicle, presence or absence of the postcoracoid process and from of the ventral element of the postclavicle.

Based on the first three of these features, the constitution of the shoulder girdle can reasonably be classified into the following two types: Type 1 is represented by most of the carangid fishes except the subfamily Trachinotinae which belongs to Type 2. Type 1 is, however, so much diversified in structure that this ought to be further subdivided into three sub-types (Table 10). In Type 1, which is more prevalent than Type 2, the posttemporal is deeply bifurcated in front, and has the dorsal branch articulated to the epiotic and the ventral one to the opisthotic, and the dorsal element of the postclavicle is wide in area, crescentic in form, and with the greatest width more or less exceeding that of the supraclavicle. Of the subdivisions of Type 1, Sub-type 1, which is represented by *Seriola*, *Naucrates* and *Elagatis*, shows the most primitive characters, such that, the postcoracoid process of the hypocoracoid is well-developed, the external shelf of the clavicle makes with the internal one an angle approximating to a right angle, and the relatively wide ventral element of the postclavicle gradually tapers downward, without taking a

Table 10.
3 sub-types of the shoulder girdle in Japanese Carangidae (Type 1)

Sub-type	Characters			Genera
	Postcoracoid process	Ventral element of postclavicle	External shelf	
1	well-developed	rather wide, without rib-like projection	making with internal shelf an approximately right angle	*Seriola* *Naucrates* *Elagatis*
2	undeveloped	aciform or rib-like from	making with internal shelf an approximately right angle	*Chorinemus* *Caranx* *Citula* *Atropus* *Alectis* *Gnathanodon* *Uraspis* *Carangoides* *Kaiwarinus* *Megalaspis* *Longirostrum* *Selaroides* *Atule* *Trachurus* *Trachurops*
3	undeveloped	aciform or rib-like from	making an actue angle	*Decapterus*

needle- or rib-like form. Sub-type 2, including most of the genera, is quite different from the preceding in that the postcoracoid process is undeveloped and the ventral element of the postclavicle takes the form of a needle or resembling a rib extending the whole length, or, at least the lower half of the bone. Sub-type 3 to which *Decapterus* belongs is the most specialized of Type 1, and has the external and internal shelves that meet each other in an acute angle.

Type 2, involving *Trachinotus*, is obviously more highly specialized than Type 1 and is characterized by that the ventral branch of the posttemporal is much reduced in length, remaining in a slight bulge, that the main portion of this bone is combined with the opisthotic by a long suture, and that the dorsal element of the postclavicle is strongly narrower than the supraclavicle.

8. Pelvic girdle

The comparative study of the pelvic girdle and the application of the results to the taxonomy of the Carangidae have never been successfully made. The author's study proves that the features of this girdle may serve for the separation of the genera, or the species, but they are insufficient for making out something of phylogenetical significance.

The pelvic girdle lying in the thoracic region is composed of a pair of thin, horizontal plates, their anterior halves being interposed between the lower anterior parts of the clavicles to which they are firmly attached. When viewed from above or from below the girdle is usually an elongate equilateral triangular in general shape, gradually, or somewhat rapidly narrowing forwards. Each of the bones is raised on the inner side along the median line into a ridge, and is reinforced on the outer side by two longitudinal keels running the dorsal and ventral borders. These are the suprapelvic keel and subpelvic keel of Matsubara (1943) (Fig. 45, A). Between these, another longitudinal, more or less conspicuous keel, which will be called interpelvic keel (Fig. 45, A), is developed in *Megalaspis cordyla*, *Citula plumbeus*, *C. dinema*, *C. malabaricus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Atropus atropus*, *Carangoides jordani*, *C. hemigymnostethus*, *Atule djeddaba*, *Gnathanodon speciosus*, *Uraspis helvolus*, *Alectis ciliaris*, *A. major*, *Trachinotus bailloni*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagatis bipinnulata* and *Chorinemus orientalis*. The keel is scarcely developed in *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus*, *Kaiwarinus equula*, *Longirostrum delicatissimus*, *Atule affinis* and *Selaroides leptolepis*. In the immediate neighbourhood of the hind end each half of the girdle bears the condyle for the reception of pelvic fin and sends off further backward a spine, Matsubara's (1943) so called postpelvic process (Fig. 45, A). The processes of both sides are always united with each other at the base though separated at the other end. They are coalesced together extending their entire length without forming an apical fork in *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *Atropus atropus*, *Trachinotus bailloni* and

Chorinemus orientalis. The length of the process relative to the same of the girdle also varies. If the length of the principal part of the girdle (from the fore end to

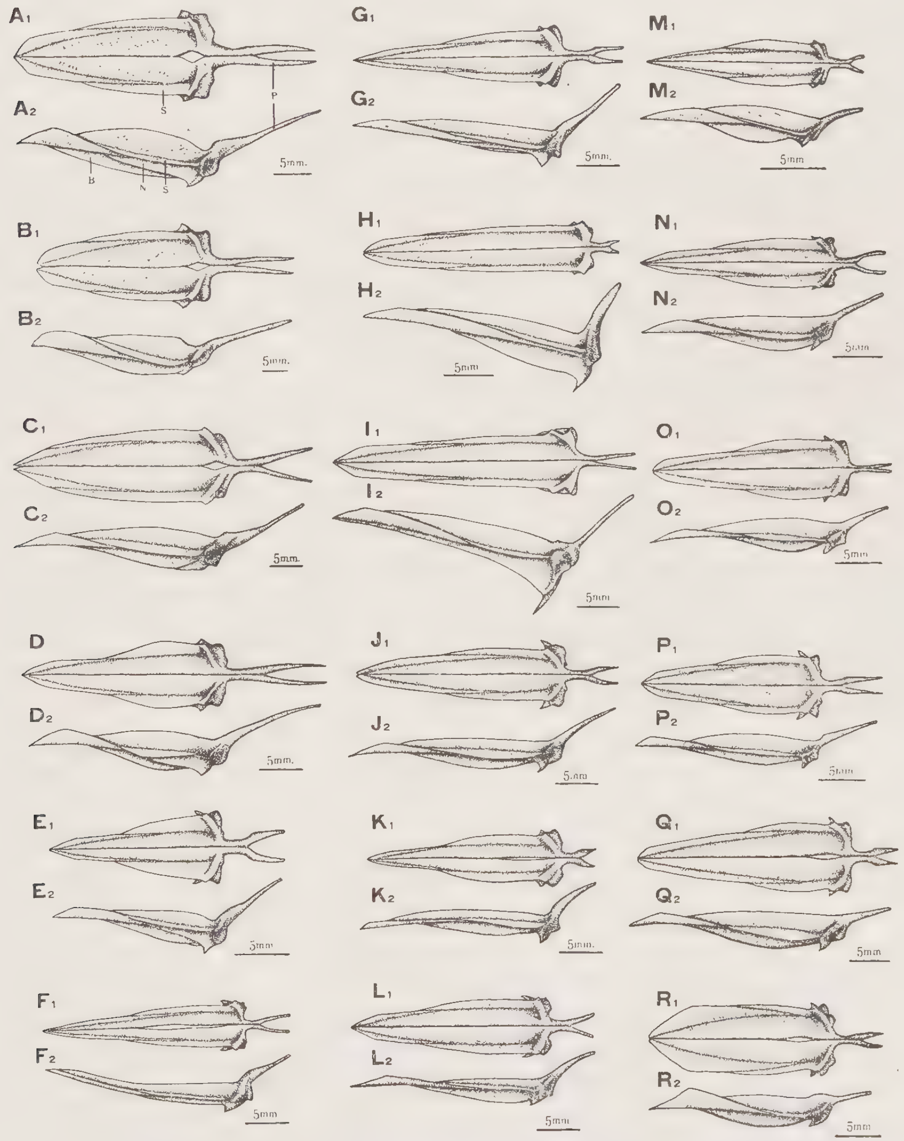

Fig. 45. Outline of the pelvic girdle in 18 species. A_1, dorsal aspect of the girdle; A_2, lateral aspect of the same. B, subpelvic keel; N, interpelvic keel; P, postpelvic process; S, suprapelvic keel. A, *Seriola purpurascens*; B, *S. quinqueradiata*; C, *Naucrates ductor*; D, *Megalaspis cordyla*; E, *Caranx xanthopygus*; F, *Carangoides hemigymnostethus*; G, *Gnathanodon speciosus*; H, *Atropus atropus*; I, *Alectis ciliaris*; J, *Longirostrum delicatissimus*; K, *Kaiwarinus equula*; L, *Atule djeddaba*; M, *Selaroides leptolepis*; N, *Atule affinis*; O, *Trachurops crumenophthalmus*; P, *Trachurus japonicus*; Q, *Decapterus maruadsi*; R, *D. lajang*.

the pelvic angle) with that of the postpelvic process (from the latter to the extreme hind end) are compared the ratio is 1.8 to 2.5 in *Megalaspis cordyla*, *Caranx hippos*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor* and *Elagatis bipinnulata*, 2.6 to 3.0 in *Trachurus japonicus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. ishikawai* and *Gnathanodon speciosus*, 3.1 to 4.0 in *Decapterus russellii*, *Citula malabaricus*, *Carangoides hemigymnostethus*, *C. jordani*, *Caranx melampygus*, *C. bixanthopterus*, *Atropus atropus*, *Longirostrum delicatissimus*, *Atule djeddaba*, *A. affinis*, *Selaroides leptolepis*, *Uraspis helvolus*, *Alectis ciliaris*, *A. major* and *Chorinemus orientalis*, and 4.1 to 6.3 in *Decapterus macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus*, *Citula plumbeus*, *C. dinema*, *Kaiwarinus equula* and *Trachinotus bailloni*. Along the mid-ventral line extending forward from the vicinity of the base of the postpelvic process each half of the girdle is usually raised into a lamellar process which Matsubara (1943) termed the suprapelvic process (Fig. 45, A). The girdle is slender and elongate and yet its width relative to its length greatly varies. Length of the girdle is less than 3.5 times the width across the pelvic angles in *Trachurus japonicus*, *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Megalaspis cordyla*, *Trachurops crumenophthalmus*, *Citula dinema*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Gnathanodon speciosus*, *Atule djeddaba*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor* and *Chorinemus orientalis*, whereas more than 3.5 times in *Citula plumbeus*, *C. malabaricus*, *Kaiwarinus equula*, *Carangoides jordani*, *C. hemigymnostethus*, *Atropus atropus*, *Uraspis helvolus*, *Selaroides leptolepis*, *Atule affinis*, *Alectis ciliaris*, *A. major* and *Trachinotus bailloni*. The girdle is strongly narrowed, having width slightly larger than, or subequal to the depth measured in the region of pelvic angle in *Alectis ciliaris*, *A. major*, *Atropus atropus* and *Citula plumbeus* (Fig. 44, H•I).

Discussion

In the carangid fishes, so far as the pelvic girdle is concerned, its anatomical features hardly furnish us with any sound ground for their availability for the taxonomy. The following characters, however, may be subservient to the purpose of classifying the present family: 1) form and relative length of the postpelvic process, 2) development of the interpelvic keel and 3) relative width of the pelvic girdle. The pelvic girdle can be classified into four types, if account is taken of these characters. The first type, which includes *Seriola*, *Naucrates* and *Elagatis*, is peculiar in that the interpelvic keel is well-developed, anteriorly extending beyond the fore end of the marginal lamella which occupies the posterior half of the girdle, in that the suprapelvic keel is highly elevated in its anterior part, and in that the subpelvic keel reaches near the fore end of the girdle (Fig. 45, A•B•C). The second type is represented by *Megalaspis*, *Caranx*, *Carangoides*, *Gnathanodon*, *Uraspis*, *Trachinotus* and *Chorinemus*, and the species *Citula dinema*, *C. malabaricus* and *Atule djeddaba*, in all of which the development of interpelvic keel is more or less conspicuous, and the girdle has the width smaller than its own depth (Fig. 45, H•I•L). The third type,

which comprises *Karwarinus*, *Longirostrum* and *Selaroides* as well as *Atule affinis*, has the girdle strongly narrowed and the interpelvic keel poor in development (Fig. 45, J·K·M·N). The last type, including *Trachurus*, *Decapterus* and *Trachurops*, possesses the girdle generally resembling that of the preceding type but different in its wideness and depression (Fig. 45, O·P·Q·R).

9. Scutes

To our knowledge, of all the members of Pisces, the Carangidae is peculiar, at least, in the possession of stout scutes arranged in a single row on the lateral line. Presence of such external bones may probably represent one of the important characteristics of the Carangidae, and developmental degree of these bones may effectively be used as a criterion for defining genera, or species.

As in other skeletal structures, comparative study of the scutes will furnish us some information as to the interrelationships among genera and subfamilies and as to their availability for systematizing the family. Observation was made with respect to the scute with the largest dorso-ventral calibre.

Presence or absence of scutes and, if present, extent of their development are the matter first to be considered. Based on these points, the Carangidae can distinctly be divided into three types of allied forms. The first type, which comprises *Trachinotus bailloni*, *Seriola quinqueradiata*, *S. purpurascens*, *Naucrates ductor*, *Elagatis bipinnulata* and *Chorinemus orientalis*, has no scute. The second type, including a greater part of the carangid fishes, has the scutes which show varying degree of development only on the posterior straightened portion of the lateral line. This group is again divisible into three minor types different in the shape of scute. The first sub-type, which involves *Citula armatus*, *C. plumbeus*, *C. dinema*, *C. malabaricus*, *Kaiwarinus equula*, *Carangoides jordani*, *C. hemigymnostethus*, *Longirostrum delicatissimus*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus*, *C. ishikawai*, *Selaroides leptolepis*, *Gnathanodon speciosus*, *Alectis ciliaris* and *A. major*, has the wide scute with blunt ends. Among these species enumerated, the last three are different from the rest in having round scutes, but armed posteriorly short and feeble spines. The scute of the second sub-type, which is represented only by *Uraspis helvolus*, bears a certain resemblance to that of the preceding sub-type in general appearance except for the possession of a median keel which is enlarged in front into a disc ending in a stout spine. The third sub-type, including *Decapterus russellii*, *D. macrosoma*, *D. muroadsi*, *D. lajang*, *D. maruadsi*, *D. akaadsi*, *Trachurops crumenophthalmus*, *Atule djeddaba*, *A. affinis* and *A. miyakamii*, has the narrow scutes with upward and downward prolongation and acuminating forwards. In the third types, to which *Trachurus japonicus* and *Megalaspis cordyla* belong, the acutes are found extending entire length of the lateral line. In the former of these species the scutes, which are not particularly stout, resemble to some extent those of the preceding sub-type in general appearance, but those present on the curved region of the lateral line are posteriorly spineless, possessing

an aperture of sensory canal at the center. In the latter species the scutes are exceedingly stout, attenuating upward and downward, with sharp, backward spines in the middle of the posterior margin, but without aperture of sensory canal.

Table 11.
Number and relative size of scutes in Japanese Carangidae.

Species	Number of scutes	Ratio between dorso-ventral calibre of scute and diameter of eye
Caranx sexfasciatus	30—31	0. 55—0. 67
Caranx xanthopygus	30—33	0. 54—0. 69
Caranx melampygus	37—38	0. 56—0. 65
Caranx bixanthopterus	34—38	0. 43—0. 52
Caranx hippos	45	0. 49
Caranx ishikawai	30	0. 50
Citula armatus	19	0. 27
Citula plumbeus	21—25	0. 27—0. 29
Citula dinema	27	0. 46—0. 52
Citula malabaricus	25—27	0. 18—0. 19
Atropus atropus	34—35	0. 33—0. 35
Kaiwarinus equula	28—31	0. 22—0. 25
Carangoides jordani	25	0. 32—0. 34
Carangoides hemigymnostethus	25—28	0. 32—0. 35
Longirostrum delicatissimus	24—30	0. 34—0. 42
Selaroides leptolepis	30—33	0. 20—0. 22
Gnathanodon speciosus	18—19	0. 36—0. 39
Alectis ciliaris	11	0. 15—0. 25
Alectis major	8	0. 12
Uraspis helvolus	34—37	0. 33—0. 42
Atule djeddaba	57—59	0. 49—0. 52
Atule affinis	41—44	0. 73—0. 79
Atule miyakamii	37	0. 66
Trachurops crumenophthalmus	35—36	0. 36—0. 55
Decapterus russellii	40—45	0. 62
Decapterus macrosoma	26—29	0. 40—0. 51
Decapterus muroadsi	33	0. 44—0. 53
Decapterus lajang	29—30	0. 43—0. 52
Decapterus maruadsi	33—35	0. 72—0. 80
Decapterus akaadsi	34—36	0. 67—0. 69
Trachurus japonicus	69—72	0. 98—1. 04
Megalaspis cordyla	48—59	2. 10—1. 98

The number of scutes and their vertical calibre of the largest member relative to the diameter of the eye are given in Table 11. The number is largest in Type 3, growing smaller is Sub-type 3, 1 and 2 of Type 2 in due order, and is smallest

in Alectis belonging to Sub-type 1. The vertical calibre relative to the eye diameter is large and more than 0.4 time in Type 3, Sub-type 3 of Type 2, *Citula dinema*, *Caranx sexfasciatus*, *C. xanthopygus*, *C. hippos*, *C. melampygus*, *C. bixanthopterus* and *C. ishikawai*. It is relatively small and less than 0.3 time in *Citula armatus*, *C. plumbeus*, *C. malabaricus*, *Kaiwarinus equula*, *Selaroides leptolepis*, *Alectis ciliaris* and *A. major*.

Discussion

It is far from unlikely that Type 1, which has no scute is more primitive than others and Megalaspinae of Type 3 which bears stout ones extending entire length of the lateral line, is more highly specialized. Nothing has been known about the function of the scutes, but the present author is of the opinion, that they have transformed from the ordinary scales so as to serve as discs protecting the lateral organ, and play a role in receiving vibration generated by the water-movement near the surface and in transmitting this to the lateral line nerve.

10. Vertebral column

Up to the present, in Scorpaenicae (Matsubara, 1943), Gempylidae (Matsubara and Iwai, 1958), Serranidae (Katayama, 1959), Soleina (Ochiai, 1959) and Pentapodidae (Akazaki, 1959) the constitution of the vertebral column has been successfully used for disclosing the interrelationship among genera, subfamilies and families. The vertebral column of the Carangidae were fully examined by Starks (1911) with reference to 21 representative species. The following are the results of the study on the Japanese carangid fishes.

Number of vertebrae:

The abdominal vertebrae are, without exception, 10 in number, but the caudal vertebrae somewhat vary (Table 12).

Parapophyses:

Although the parapophyses mostly begins with the fourth, or fifth vertebra, it is somewhat difficult, owing to the smallness of their sizes, to find out first two, or three pairs of parapophyses in the specimens preserved in formalin. The terminal one to four pairs have the members of both sides connected with each other above the vertebrae to form a bony bridge, which encircles a haemal canal. The bony bridge is present in the last pair of parapophyses in *Seriola*, *Naucrates*, *Elagatis* and *Chorinemus*, in the last two pairs in *Trachinotus*, *Megalaspis*, *Alectis*, *Longirostrum* and *Trachurus*, in the last three in *Caranx*, *Trachurops*, *Selaroides*, *Atule*, *Kaiwarinus*, *Carangoides* and *Atropus*, and in the last four in *Citula*, but absent from any pair in *Decapterus*, *Gnathanodon* and *Uraspis*.

Inferior vertebral foramina:

Oval or round foramen, the inferior vertebral foramina of Starks (1911), is usually found at the base of the haemal arch and parapophyses, and greatly varies in the development. A consideration will be given to the development of the fora-

A

B

C

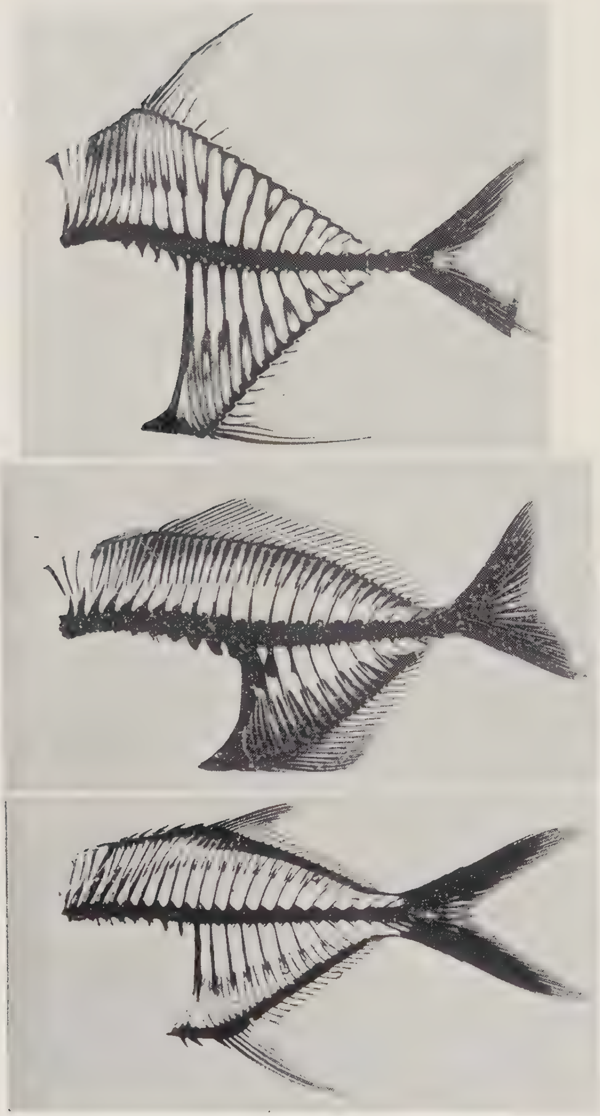

Fig. 46. Lateral aspect of the vertebral skeleton. A, *Citula plumbeus*; B, *Gnathanodon speciosus*; C, *Caranx xanthopygus*.

mina in connection with that of the parapophyses and the first haemal arch. The foramina is present in the four parapophyses and the first haemal arch of *Citula* and *Megalaspis* (Fig. 46, A), of the last three parapophyses and the first haemal arch of *Caranx*, *Atropus*, *Carangoides*, *Uraspis*, *Gnathanodon*, *Alectis* and *Selaroides* (Fig. 46, B·C; Fig. 47, D·E), in the last two parapophyses and the first haemal arch of *Atule* (Fig. 48, G), and in the first haemal arch of *Trachurops* and *Decapterus* (Fig. 48, I·J). The foramina is greatly enlarged in *Megalaspis* and *Citula*, much reduced in size in *Alectis*

and *Uraspis*, and entirely absent in *Naucrates*, *Seriola*, *Elagatis*, *Trachinotus*, *Chorinemus*, *Kaiwarinus* and *Longirostrum* (Fig. 47, F; Fig. 48, H; Fig. 49).

D

E

F

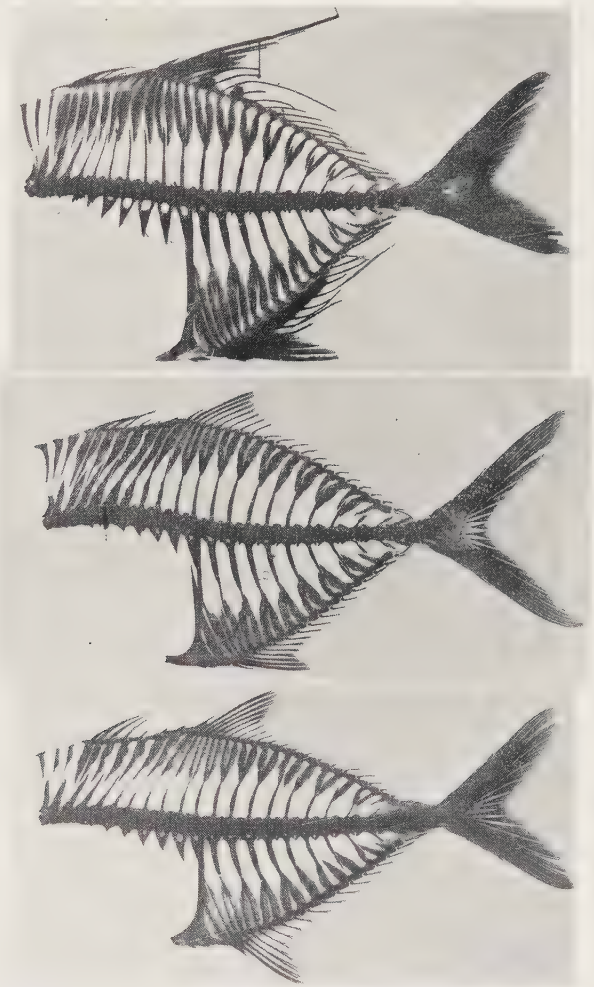

Fig. 47. Lateral aspect of the vertebral skeleton. D, *Alectis ciliaris*; E, *Uraspis helvolus*; F, *Trachinotus bailloni*.

Imperfect interneural spines:

There are three interneural spines inserted in front of the one which carries the first dorsal spine. They do not participate in supporting the dorsal fin ray, and were named the imperfect interneural spines by Akazaki (1959). Their position in relation to the anterior neural spines is divisible into two types. In the first type which involves *Seriola*, *Elagatis*, *Chorinemus* and *Trachinotus*, the interneural spines are inserted one between each two of the first three neural spine besides the one placed in front of the first neural spines (Fig. 47, F; Fig. 49, K·L·N). In the second

Table 12.
Number of caudal vertebrae in Japanese Carangidae.

Species	Number of specimens	Number of caudal vertebrae		
		14	15	16
Chorinemus orientalis	2			2
Trachinotus bailloni	2	2		
Seriola quinqueradiata	4	4		
Seriola purpurascens	5	5		
Naucrates ductor	2		2	
Elagatis bipinnulata	2	2		
Megalaspis cordyla	1	1		
Caranx sexfasciatus	5	4	1	
Caranx xanthopygus	3	1	2	
Caranx melampygus	3	3		
Caranx bixanthopterus	3	3		
Caranx hippos	1	1		
Caranx ishikawai	1	1		
Citula armatus	1	1		
Citula plumbeus	2	2		
Citula dinema	1	1		
Citula malabaricus	2	2		
Atropus atropus	2	2		
Uraspis helvolus	5	5		
Gnathanodon speciosus	1	1		
Alectis ciliaris	5	5		
Alectis major	1	1		
Carangoides jordani	1	1		
Carangoides hemigymnostethus	1	1		
Kaiwarinus equula	6	6		
Longirostrum delicatissimus	5		5	
Selaroides leptolepis	1	1		
Atule djeddaba	1	1		
Atule affinis	1	1		
Atule miyakamii	1	1		
Trachurops crumenophthalmus	5	5		
Decapterus russellii	5	5		
Decapterus macrosoma	4	4		
Decapterus muroadsi	10	10		
Decapterus lajang	9	9		
Decapterus maruadsi	10	10		
Decapterus akaadsi	5	5		
Trachurus japonicus	45	45		

type which includes the rest of genera the first interneural spine precedes the first

neural spine as in the first type, but the succeeding two interneural spines are interposed between the first two neural spines.

Union or separation of the first haemal spine and the first interhaemal spine:

As stated by Starks (1911) and Matsubara (1955), both the first haemal spine and the first interhaemal spine are neither enlarged nor pressed against each other in *Seriola*, *Naucrates* and *Elagatis*, whereas they are broadened to be pressed against each other in other genera.

Forms of anterior haemal spines:

The haemal and neural spines are attenuating gradually distally. *Uraspis*, however, is unique in that the second to fourth haemal spines possess a disc-like expansion on their anterior margins. The second is the largest in the area of expansion which extends for the upper half and nearly comes in contact with the first haemal

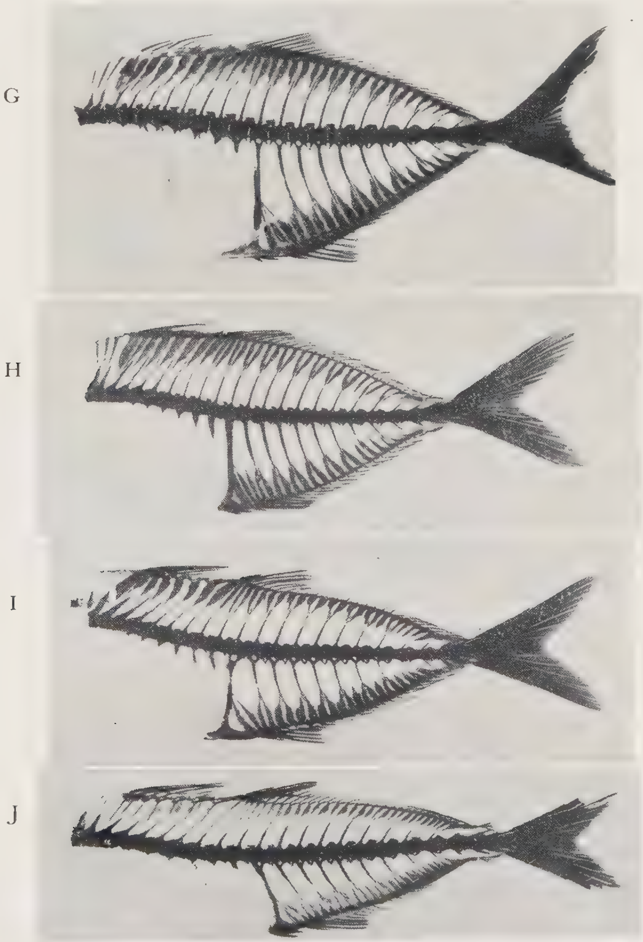

Fig. 48. Lateral aspect of the vertebral skeleton. G, *Atule djeddaba*; H, *Longirostrum delicatissimus*; I, *Trachurops crumenophthalmus*; J, *Decapterus maruadsi*.

spine. The other two spines are not so strongly expanded as in the second, remaining to show a smaller expansion only on the upper one-third of their lengths; the expansion is smaller in the fourth (Fig. 46, E).

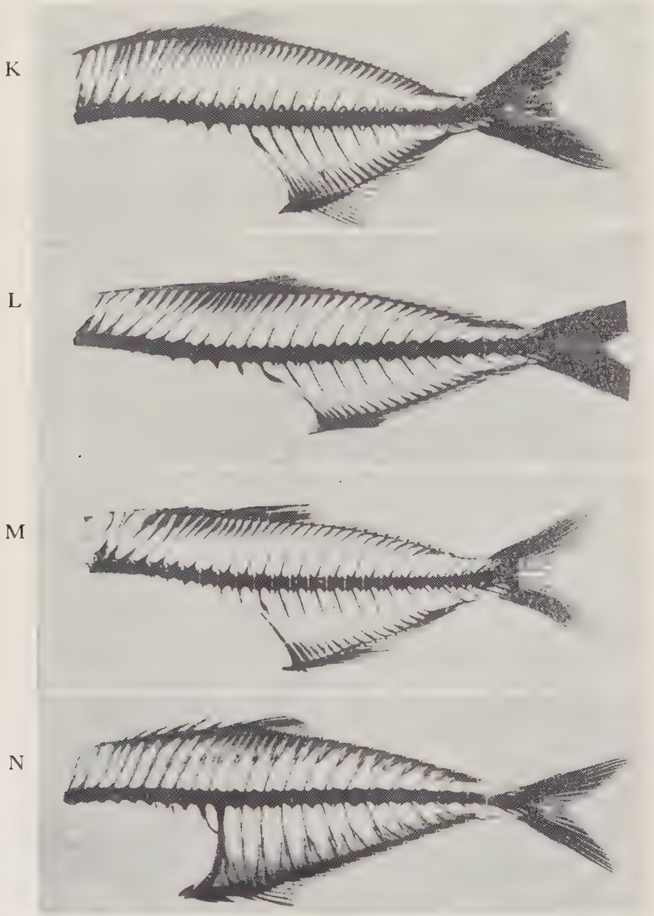

Fig. 49. Lateral aspect of the vertebral skeleton. K, *Seriola purpurascens*; L, *Elagatis bipinnulata*; M, *Naucrates ductor*; N, *Chorinemus orientalis*.

Discussion

In the classification of the Carangidae the vertebral column does not come into question as for the present. From the statement given above, however, it may be clear that the followings are worth while the taxonomic criteria. Developmental degree of bony bridge on the parapophyses of the posterior vertebrae, some of the inferior vertebral foramina, relative positions of the imperfect interneural spines and the anterior neural spines, adjoining or non-adjoining of the first haemal spine to the first interneural spine, and forms of the anterior haemal spines.

III. Consideration on the phylogeny of the Carangidae

1. Origin of the Carangidae

No definite hypothesis has been suggested as regards the origin of the Carangidae. It appears to the author that the members of this family have arisen from the percid fishes, or from an ancestral form common to both, following respective evolutional paths. This may well be supported by the fact that the Naucratinae, which is regarded as the most primitive of the Carangidae, has many traits of character in common with the typical percid, such that 1) scales on the lateral line are undeveloped into scutes, 2) upper margin of the second suborbital bone is projecting inward to form the suborbital shelf, 3) pterygoid is slender, directed forward and with fore end not particularly enlarged, and 4) the first haemal spine is feeble, scarcely enlarged, and rather loosely attached to the equally feeble first interhaemal spine.

2. Affinities of the Carangidae to the Scombridae

On account of the close resemblance between the Carangidae and the Scombridae, the two families have frequently been united into a single suborder, or into other taxonomical categories. JORDAN and EVERMANN (1896) include those families in the Scombroidei of the order Acanthopteri and BOULENGER (1922) put them in the Scombriformes of the order Acanthopterygii. From his careful comparison of the two families with respect to their skeleton, STARKS (1910, 1911) recognizes the initimate relation of the two families. He states that, in contrast to the Carangidae, all the genera of which have well-developed suborbital bony system, the Scombridae has nothing but suborbital chain of inconspicuous bones, which are scarcely different from ordinary scales of the cheek, in *Scomber*, which is the only genus having the perfect system. If we consider the question with special reference to this character, we may arrive at the conclusion either that the Carangidae, which finds the nearest ally in *Scomber*, has been differentiated from a certain member of the Scombridae before the degeneration of suborbital bones, or that the development of bones has been reoccupied in the Carangidae. Considered from other characters, however, we may reach another conclusion. The facts found in *Megalaspis* that the basal parts of the deeply forked caudal fin rays almost entirely cover the hypural bone, and that the caudal peduncle is provided on the sides with a strong, longitudinally running keel are both in agreement with what are found in some of the typical scombrids, suggesting the most intimate relationships of the genus to the Scombridae. In this family the first interhaemal spine is little enlarged and is not closely attached to the haemal spine of the first caudal vertebra. This is the character same as that found in *Naucrates* and *Seriola* in the Naucratinae, and reveals their close relation to the Scombridae. Generally speaking, however, *Oligoplites* and *Chorinemus* the genera of the Chorineminae, seem to be more nearly allied to the

Scombridae rather than to other subfamilies of the Carangidae. Not only the possession of a large number of more or less discontinuous fin-lets but also the non-protractile premaxillaries, a slight increase in the vertebral number and closely adjoining of the epiotics of both sides in the interior of the cranium are all in common with this family. At any rate, opinion is divided among authors as to which of those three subfamilies may have the closest affinity to the Scombridae in accordance with what character they may choose in considering the matter.

Gregory (1933), in his extensive studies of the fish skulls, emphasized the close relationships of the Carangidae to the Scombridae. Starks (1911) insists that the Carangidae shares essential characters of the skeleton with the Scombridae except in that a large part of the opisthotic is covered by the exoccipital-pterotic suture in dorsal view, in that the sclerotic bony case is not so completely developed, and in that the premaxillaries are protractile.

Based on his careful osteological analysis of the Japanese Carangidae, the author also acknowledges the presence of a close resemblance between the Carangidae and the Scombridae. He must add, at the same time, the fact that certain differences exist between them with respect to their skeletal characters. More precisely, in the Carangidae the premaxillary is protractile and rather loosely attached to the inner surface of the premaxillary with the exception of *Chorinemus*, the postmaxillary process of premaxillary with dorsi-ventrally high ascending process is well-developed, generally well-developed orbital bones accompany the suborbital shelf or lamina expanded inward on the upper margin of the second suborbital bone, the abdominal vertebrae are without exception 10 in number, and the caudal vertebrae are 14 to 16. In the Scombridae the maxillary is firmly united with the non-protractile premaxillary, forming together a pointed beak, the preorbital bone is more or less well-developed, but other suborbital bones are strongly degenerated in most of the forms except *Scomber*, and the vertebrae are far larger in number than in the Carangidae, showing a wide variation, such as 31 in *Scomber*, 31 to 64 in *Scomberomorus*, and 39 in *Thunnus* and *Katsuwonus*.

An inevitable question comes to mind which is more primitive, the Carangidae or the Scombridae. Without doubt, the former is more primitive, since the orbital bones are well-developed and the premaxillary is protractile. Both of these characteristics are generally regarded as the prevailing features of the typical percids. The vertebrae are 10+14 in number as in the case of primitive percids.

3. Relationships of the Carangidae to the near allies exclusive of the Scombridae

Matsubara (1955) placed the Carangidae together with Formiidae, Leiognathidae, Lactariidae, Menidae and Rachycentridae in the Carangina of the order Percida. Consideration will be extend to the relationships of the Carangidae to these families (excluding Lactariidae).

The Formiidae is initimately related to the Pampidae in having the body high and much compressed, in having only one dorsal fin, which is devoid of separated spinous one, in having the bases of dorsal and anal fins elongated, in the lack of separated spine in front of the anal fin, and in the absence of the ventral fin (young possesses this fin on the jugular level (KAMOHARA, 1940)). On the other hand, the Formiidae bears certain resemblance to the Carangidae in that the premaxillary is protractile, in that the orbital bones are well-developed, consisting of one preorbital and five suborbital bones, with inwardly expanding suborbital shelf on the upper margin of the second suborbital, in that the supraoccipital crest extends so far forward as to cover entire length of the cranium, in that the stout first interhaemal spine forming together a curved frame which borders the posterior boundary of the abdominal cavity, and in that the abdominal and caudal vertebrae are 10 and 15 in number.

As pointed out by STARKS (1911) and MATSUBARA (1955), the Leiognathidae shows certain affinities to the Carangidae in the possession of protractile premaxillary and 10+14 vertebrae, but is different in having the suborbital chain of bones incompletely developed, in the supraoccipital crest not reaching so far forward, in the alisphenoids meeting together on the midline, in the interhyal articulating to the lowest part of the very short symplectic, and in the epihyal connected with the interopercle.

The Menidae is allied to a certain extent to the genus *Alectis* of the Carangidae in the body high and much compressed, in the premaxillary protractile, in the supraoccipital crest extending nearly entire length of the cranium, and in the vertebrae 10+14 in number, but is distinguished from the latter by the absence of anal spine, by the non-scaly body, by the fronto-supraoccipital crest being doubled in front with sides widely apart so as to interpose a shallow and narrow median cavity, by the external expansion of the ectethmoid having a deep notch in the anterior region, and by the head of the vomer being provided with a large, transversely perforating foramen.

The Rachycentridae has a certain affinity to the genus *Elagatis* of the Carangidae in having the protractile premaxillary and the well-developed orbital bones, but is remote in the absence of suborbital shelf, in the very low, rudimentary postmaxillary process present near the posterior extremity of the upper margin of the premaxillary, in the wide, much depressed cranium, in the small-sized supraoccipital, in the lack of the fronto-supraoccipital crest, and in the narrow ceratohyal which is deprived of the ceratohyal window.

As stated above, Formiidae, Leiognathidae, Menidae, and Rachycentridae show respectively several points of differences from the Carangidae and they are by no means similar in the extent of their affinity to this family. Now let us consider to what extents the principal characteristics of the Carangidae are represented in those families. Development of the fronto-supraoccipital crest, presence of the ceratohyal window, formation of the suborbital shelf or lamina on the upper mar-

gin of the suborbital, and insertion of two spines in front of the origin of the anal fin ought to be regarded as the important characteristics of the Carangidae. The Formiidae is distinguished from this family by the absence of two spines in front of the anal fin, but resembles in other three features. The Menidae shares numbers of characteristics with the Carangidae except for the absence of two spines in front of the anal fin. The former, however, is peculiar in the configurations of the fore end of the fronto-supraoccipital crest, of the orbital wing on the ectethmoid and of the lateral face of the vomer head. These facts apparently indicate certain affinities of the Menidae to the Carangidae which represents the main stem of the suborder Carangina, though less closely related than in the those of the Formiidae. The Leiognathidae and the Rachycentridae, being least close to Carangidae are essentially different in the median crest of supraoccipital not extending as far as the frontals, and in the absence of the suborbital shelf or lamina, and their relationships to the Carangidae are further remote.

As regards the propriety of assigning those four families to the suborder Carangina, it appears reasonable to place the Formiidae and Menidae in the suborder Carangina, but it is inadequate to add the Leiognathidae and Rachycentridae. On the latter point further confirmation is necessary.

4. Differentiation of the genera of Carangidae

The Carangidae is classified into five subfamilies, Naucratinae, Chorineminae, Trachinotinae, Caranginae and Megalaspinae. These show varieties of their own morphological features. The characteristics significant for disclosing their phylogeny are the configuration of the orbital bones, shape and capability of the protrusion of the premaxillary, presence or absence of the supramaxillary, form of the pterygoid, same of the preorbital region of cranium, height of the fronto-supraoccipital crest, shape of the parasphenoid, number of the caudal vertebrae and joining or disjoining of the first haemal spine with the first interhaemal one. If the account is taken of these, it may be safe to assume that the ideal progenitor of the Carangidae has been furnished with the following features: 1) scales on the lateral line are not developed into scutes, 2) orbital bony system is well-developed, 3) suborbital shelf is present inside the upper border of the second suborbital bone, 4) premaxillary is moderately protractile, with ascending process attaining higher than the articular process and with postmaxillary process moderately projecting, 5) the supramaxillary is present in one, 6) the fore end of pterygoid is not particularly enlarged, 7) the olfactory cavity is absent, 8) the median crest of the supraoccipital does not reach so far forward as to be inserted between frontals, 9) the caudal vertebrae are 14 in number, and 10) the first haemal spine is neither stout nor thick ened and is rather loosely attached to the equally feeble first interhaemal one. Such a progenitor is, of course, not met with in any of the above-named subfamilies. If, however, the constitution of the fronto-supraoccipital crest is left out of account,

the Naucratinae is the nearest to this ideal form. The Chorineminae is presumed to have deviated from the rest in an earlier stage of the evolutionary process to the Carangidae to follow its own. This is plausible from the peculiarities in the Chorineminae, such that, the premaxillary is narrowly elongated, with short ascending process, and without postmaxillary process, the maxillary is slender, the lower jaw is neither thick nor with interosseous space between the upper arm of the dentary and the dorsal border of the articular owing to their close mutual contact, branchiostegal rays are present in 8, the fin-lets inserted behind the dorsal and anal fins are more or less discontinuous, caudal vertebrae are 16 in number, and the epiotics of both sides are in contact with each other in the interior of the cranium. Because of these peculiarities, the Chorineminae appears to be more highly specialized than the other subfamilies. The Trachinotinae is more primitive, resembling the ancestral form of the Carangidae in the absence of scutes, in the protrusibleness of premaxillary to a certain extent, in the premaxillary having long ascending process and semicircular postmaxillary process, in the slenderness of the fore part of pterygoid, and in the caudal vertebrae 14 in number. Notwithstanding these primitive characters, the family has its own peculiarities: absence of supramaxillary, forward extension of the median crest of supraoccipital, occupying a greater part of the fronto-supraoccipital crest, expansion of the ventral border of the parasphenoid which is flattened in the posterior part, and the short, rudimentary ventral branch of the posttemporal. From these characters it may be deducible that similarly to Chorineminae the Trachinotinae also represents an off-shoot having deviated from the main stem leading to the Carangidae in an earlier stage of its evolutionary process. Moreover, the comparative study of jaw bones suggests that the Trachinotinae is more primitive than the Chorineminae.

The Caranginae, the evolution of which represents the main stem of the phylogenetical tree of the Carangidae, may probably have arisen from the extinct original form passing through a near relative of the Naucratinae. This may be proved by the facts that, despite the maintenance of such primitive features as the protrusibleness of premaxillary and the presence of one supramaxillary, the Caranginae is characterized by such specializations that the suborbital shelf is almost entirely disjoined from the upper margin of the second suborbital bone, being reduced into a so-called suborbital lamina, that the scutes are well-developed along entire length of the lateral line, or on the posterior straightened portion of the same, and that the strong first haemal spine is firmly united with the strong first interhaemal spine, forming together a curved frame which borders the hind end of abdominal cavity. The Megalaspinae is in agreement with the Caranginae in various features, but disagrees in carrying on the sides along the entire length of the lateral line very stout scutes which are not found in any other subfamilies, and in the presence of several fin-lets behind the dorsal and anal fins. It may be appropriate to say that the Megalaspinae represents another off-shoot having branched from the stem which leads from the ancestral form of the Naucratinae to the Caranginae. The

facts herefore mentioned throw light on the relationship among the five subfamilies. Next, let us consider the generic differentiation within each of the subfamilies Naucratinae and Caranginae.

Naucratinae:

Of the genera *Seriola*, *Naucrates* and *Elagatis*, the first is somewhat different from the rest in the possession of the suborbital process, showing a closer affinity to the Carangidae. In spite of their resemblance to the ideal original form of the Carangidae in the form of the suborbital shelf, the rest of the genera are respectively characterized by their own peculiarities. In *Naucrates*, the glossohyal and epihyal are very wide, the anterior shelf of the clavicle is broad, and spines of the first dorsal fin are separated one from another and not combined together by a fin membrane. In *Elagatis*, the olfactory cavity, which is roofed by the anterior extension of the frontal, conspicuously developed, the urohyal has a medio-ventral longitudinal crest in addition to the lateral wings, and a single fin-let is inserted behind the dorsal and anal fins respectively.

Caranginae:

A large number of genera are referable to the subfamily Caranginae. Because of their intimate mutual relationships, there are no appreciable difference among them. They are roughly divisible into following five groups: The first group comprises *Caranx*, *Citula*, *Atropus*, *Kaiwarinus*, *Carangoides* and *Gnathanodon*, the second is represented by *Uraspis*, the third by *Alectis*, the fourth by *Selaroides*, and the fifth by *Longirostrum*, *Atule*, *Trachurops*, *Trachurus* and *Decapterus*. In all of these except the fifth group the exoccipital has the zygapophyses, which surmount on the atlas, join each other, whereas in the fifth these more or less widely separated. This points deviation of the fifth group from the others. Among the representatives of the first group, *Caranx* resembles *Seriola* of the subfamily Naucratinae in the constitution of the preorbital region of the cranium, of the superior portion of the mesethmoid and of the jaw bones. Accordingly, *Caranx* shows more generalized type of structure than other genera do, though its suborbital process is disc-like and peculiarly compressed. Both *Citula* and *Atropus* bear a certain resembrance to *Caranx* on one side, but each has own peculiarities. *Citula* has no scale on the breast. *Atropus* has strongly compressed body, abdominal part of which is deeply grooved along the mid-ventral line to receive the whole of depressed ventral fins. *Kaiwarinus*, *Carangoides* and *Gnathanodon* are more highly specialized, since they have somewhat well-developed olfactory cavity. Among them, *Gnathanodon* seems to be the most highly differentiated on account of the following peculiarities: the mesethmoid-vomerine keel, assuming a form of thin plate, is strongly elevated, the maxillary widened with its external fork particularly enlarged, the ascending process of the premaxillary is highly projecting, the ventral edge of parasphenoid is provided with a well-developed protuberance which contains a conical cavity opening backward. *Uraspis* which belongs to the second group bears a resembrance to *Caranx* in the form of the pre-

orbital region of cranium. *Uraspis*, however, may be more highly specialized than the members of the first group in that the keel on the scutes is expanded into a disc terminating in front a spine, in that the skeleton is as a whole fragile in its structure, and in that the posterior opening of the myodome is entirely closed. Although *Alectis*, the representative of the third group, is very similar to *Atropus* of the first group in its tall, much compressed body form, that genus is farther advanced than this genus in specialization. This may come from the characteristics *Alectis* has. That is: every spine on the first dorsal fin is rather rudimentary and is not connected with adjoining one by the fin membrane, anterior rays of the second dorsal and anal fins are produced into very long filaments, the olfactory cavity is shallow but well-developed, and the orbital wing of the ectethmoid is rounded in outline and continues gracefully upward to the frontal without forming an angle. *Selaroides*, the representative of the fourth group, is strongly specialized, since its mesethmoid-vomerine keel is highly elevated, assuming a form of thin plate, the olfactory cavity is very narrow and deep, the premaxillary has the rostral cartilage triangular in form and the elongate ascending process, and the reduced suborbital lamina is in contact with the upper margin of the first suborbital bone. Of the genera belonging to the fifth group, *Trachurus*, *Trachurops* and *Decapterus* are somewhat more highly specialized than the rest, since their ascending process of premaxillary is shorter than the articular process.

Considering from the fact herefore stated, the disposition of genera in conformity with their degree of differentiation may be as follows.

IV. Taxonomy

1. Methods of measurement

The counting and measurements of the various parts of the body are taken as in the following way.

Standard length: from the tip of snout to the junction of the posterior margin of the hypural and the bases of the caudal fin.

Head length: the one taken horizontally from the tip of the snout and the posterior end of the opercular flap.

Eye diameter: horizontal calibre

Interorbital space: distance between the middle points of the upper margins of the two orbits.

Maxillary length: from the anteriormost of the premaxillary (the symphysis of the upper jaw) to the upper posterior corner of the maxillary.

Height of fin: length of the longest fin ray.

Length of fin base: distance from the base of the first fin ray to the same of the last fin ray.

Length of pectoral fin: from the middle of the base to the tip.

Length of ventral: from the base to the tip.

Depth of the caudal peduncle: shortest vertical calibre of the peduncle.

Length of the caudal peduncle: the one from the base of the last anal fin ray to the lower end of the base of the caudal fin.

Length of the ventral spine: represented by the same of the outer spine.

Length of anal spine: represented by the same of the anteriormost spine.

Number of vertebrae: the hypural is counted among the vertebrae, and the first vertebra with well-developed haemal spine is taken for the first caudal vertebra.

Since the detailed description on the external morphology of the Carangidae has been given by Wakiya (1924), the present study lays stress chiefly upon the osteological features of the family. Owing to the scantiness of the available specimens in the author's hand, it was impossible, to his regret, to introduce the statistical treatment into the study. He desires eagerly a future collection of abundance of specimens would suffice the study in this field.

2. Carangidae

Fronto-supraoccipital crest well-developed. Premaxillary protractile except in Chorineminae. Supramaxillary usually present on the upper posterior edge of maxillary, but absent in rare cases. Ceratohyal window present, slit-like, elongate oval or ovate in form. Branchiostegal rays in 7, rarely in 8. Horizontal, inwardly projecting disc on the upper margin of the suborbital bone in the form either of suborbital shelf or of lamina. Abdominal vertebrae in 10, caudal vertebrae in 14 to 15, rarely in 16. Imperfect interneural spine in 3. Anal fin has two isolated spines in front of its origin.

Key to subfamilies

1a Inwardly extending horizontal disc on the upper margin of suborbital bone in the form of suborbital shelf.
  2a Ventral branch of posttemporal not very short; supramaxillary present; posterior part of parasphenoid never enlarged; basioccipital without process.
    3a Premaxillary protractile; postmaxillary process present.........**Naucratinae**
    3b Premaxillary non-protractile; postmaxillary process absent ....**Chorineminae**
  2b Ventral branch of posttemporal rudimentary; supramaxillary absent; posterior part of parasphenoid expanded sidewise on ventral edge, forming a broad plate; basioccipital with a large external process on ventral surface ....**Trachinotinae**
1b Inwardly extending horizontal disc on the upper margin of suborbital bone in the form of suborbital lamina.
  4a Scutes present in posterior straightened portion of lateral line except in Trachurus, where they extend to the anterior curved portion and are perforated by the apertures of sensory groove; scutes not very stout.........**Caranginae**
  4b Scutes large, much stout, present on entire lateral line, without apertures of sensory groove............**Megalaspinae**

Subfamily Naucratinae

Body narrow dorsi-ventrally, somewhat compressed and covered by small cycloid scales. No scute on lateral line. Preorbital region of cranium wide and short. Olfactory cavity absent or poorly developed. Superior portion of mesethmoid widening sidewide and projecting anteriorly beyond frontals. Fronto-supraoccipital crest more or less highly elevated. Myodome with broad posterior perforation. Zygapophysis of exoccipital meeting the fellow of opposite side so as to be articulated to atlas. Anterior part of parasphenoid more or less widely flattened on its ventral surface. Premaxillary protractile, with ascending process somewhat highly projecting, and with rather short semicircular postmaxillary process. Branchiostegal rays 7 in number. Suborbital shelf constructed by inward expansion of the upper margin of the second or third suborbital bone. Postcoracoid process well-developed. Interpelvic keel also well-developed, with its fore end reaching near the fore end of pelvic girdle. Caudal vertebrae 14 to 15 in number. Last pair of parapophyses with or without bony bridge. Inferior vertebral foramina undeveloped. Both first haemal and interhaemal spines neither thickened, nor in contact with each other.

Key to genera

1a Suborbital process present............***Seriola***

1b Suborbital process absent.

2a Olfactory cavity absent; angle inserted between two arms of dentary about 90°; urohyal without medio-ventral longitudinal crest, but with a pair of broadly expanded lateral wings; postcoracoid process triangular in form ....***Naucrates***

2b Olfactory cavity shallow; angle between two arms of dentary about 45°; urohyal with a medio-ventral longitudinal crest; postcoracoid process linguiform ....***Elagatis***

Genus *Seriola* Cuvier

Body somewhat compressed. Scutes entirely absent. Caudal peduncle with longitudinal keel more or less well-developed. Preorbital region of cranium wide and short. Olfactory cavity undeveloped. Superior portion of mesethmoid widened from side to side and projecting anteriorly beyond frontals. Fronto-supraoccipital crest somewhat high. Myodome with broad posterior perforation. Zygapophysis of exoccipital joins the fellow of opposite side. Anterior part of parasphenoid with ventral surface widely flattened. Ascending process of premaxillary somewhat short, but distinctly separated from the articular process. Postmaxillary process widely expanded and semicircular in outline. Pterygoid slender and without upwardly projecting process at fore end. Lateral wings of urohyal moderately expanded. Preorbital bone somewhat low, with its upper margin massively bulged. Suborbital shelf large. Suborbital process short, but sharply acuminating. External shelf of clavicle wider than internal shelf, the two making together a right angle. Postcoracoid process linguiform. Lower member of postclavicle ensiform. Interpelvic keel well-developed. Last pair of parapophyses combined by bony bridge. Inferior vertebral foramina entirely absent. Imperfect interneural spines 3 in number, first of them located in front of first neural spine, and the succeeding two interposed each between every two of the first three neural spine.

Key to species

1a Postorbital region twice as long as preorbital region; pterotic window present; supramaxillary rounded at its dorso-posterior corner, and about 4.5 times as long as wide; opercle slightly longer than interopercle; mesopterygoid shorter than hyomandibular; the latter with head unarmed; urohyal almost as long as ceratohyal; posttemporal relatively high, with a slight projection at the depth of the branches............***Seriola purpurascens***

1b Postorbital region 1.7 times as long as preorbital region; no pterotic window; supramaxillary angular at its dorso-posterior corner, and about 10 times as long as wide; Opercle only slightly shorter than hyomandibular; hyomandibular provided at its head with a stout, sharp, posteriorly projecting process; urohyal longer than ceratohyal; posttemporal rather narrow, with an elongate

process inserted between dorsal and ventral branches ....***Seriola quinqueradiata***

Seriola purpurascens TEMMINCK and SCHLEGEL

Seriola purpurascens TEMMINCK and SCHLEGEL, Fauna Japonica, Poiss., p. 113, pl. 61, 1844-BLEEKER, Verh. Bat. Gen., vol. 26, p. 103, 1857-JORDAN and SNYDER, Proc. U. S. Nat. Mus., vol. 24, p. 352, 1901-JORDAN, SNYDER, and TANAKA, Jour. Coll. Sci. Tokyo, vol. 33, p. 127, 1913-WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 228–229, pl. 36, fig. 2, 1924-OSHIMA, Philippine Jour. Sci., vol. 26, pp. 355–356, 1925.

Seriola dumerilli GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 462, 1860.

Material examined:

5 specimens, 273.0–179.0 mm long, at Owase, Mie Prefecture, November, 1957.

External:

Depth 2.82–3.03; head 3.36–3.46; from tip of snout to origin of first dorsal fin 2.82–2.93; from tip of snout to origin of second dorsal fin 2.04–2.08; from tip of snout to origin of ventral fin 3.31–3.55; from tip of snout to origin of anal fin 1.58–1.60; (numeral represents the ratio of standard length to each item). Snout 3.04–3.36; eye 4.09–4.64; interorbital space 2.80–3.04; upper jaw 2.30–2.42; height of first dorsal fin 4.26–4.78; base of the same 2.29–2.32; height of second dorsal fin 2.19–2.22; base of the same 0.71–0.62; height of anal fin 2.47–2.74; base of the same 1.16–0.86; pectoral 1.88–2.04; ventral 1.69–1.87; from anterior side of anus to origin of anal fin 3.51–5.60; length of caudal peduncle 3.94–5.40; depth of the same 3.54–4.83; ventral spine 3.94–5.40; anal spine 5.05–5.85; ratios of head length to each item. ID. VII: IID. I, 32: A. I, 19: P. i, 17.

Body compressed, half as wide as deep. Dorsal margin moderately curved from tip of snout to origin of dorsal fin. Snout obtuse, with length 1.2–1.5 times the eye diameter. Maxillary reaching anterior margin of pupil; upper jaw as long as lower jaw and well round in its dorso-posterior part owing to the curvature of upper posterior angle of supramaxillary.

Color in formalin dark greyish brown in dorsal area, gradually becoming paler downward. A comparatively distinct longitudinal band extends from upper posterior angle of eye to dorsal part of opercle. Fins somewhat blackish, anal alone edged with narrow white band.

Internal:

Material consists of a single specimen, with standard length 273.0 mm and cranial length 57.0 mm.

Rostral length 4.39; diameter of orbit 3.00; postorbital length 2.19; depth 1.68; width 1.90; interorbital width 2.42; ratios between cranial length and respective items.

Preorbital region of cranium short, and round at anterior extremity. Mesethmoid vomerine keel distinct but low. Cuneiform longitudinal area of vomer, ex-

tending from fore end of head to median shaft, crowded with villiform teeth. Superior portion of mesethmoid widening from side to side and slightly projecting forward beyond frontals. Olfactory cavity undeveloped. Lateral expansion of orbital wing of ectethmoid inconspicuous, and entirely concealed beneath frontal. Fronto-supraoccipital crest somewhat high, with height at the center of brain case 0.3 time the depth of cranium. Supraoccipital occupying 0.66 time the dorsal edge of median crest, and extending as far forward as the middle of orbit. Parasphenoid slightly curved upwards in the region beneath sphenotics, widely flattened ventrally in the region of orbital floor, roundly convex in the region of floor of myodome and highly keeled in the curved portion. Myodome widely open backwards with quadrangular aperture. Sphenotic relatively small in size. Temporal and pterotic crests well-developed, and strongly inclined outwards. Pterotic window somewhat wide, circular in outline. Posterior spine of pterotic sharp and ensiform. Zygapophyses of exoccipitals of both sides meet with each other beneath foramen magnum. Supramaxillary 0.53 time as long as maxillary, somewhat wide, with upper posterior corner rounded. Ascending process of premaxillary relatively short, 0.46 time as long as premaxillary; articular process thick, semi-circular, not surpassing ascending process, with which it makes a deep "V"-shaped notch. Postmaxillary process short, wide, and with round upper margin. Interosseous space between two arms of dentary narrow. Villiform teeth crowded forming narrow band on lower margin of premaxillary as well as on upper margin of dentary. Hyomandibular somewhat short, 0.45 time the cranial length, with narrow head; anterior two zygapophyses, which are articulated to lateral surface of cranium, distinctly apart. Metapterygoid lamina undeveloped. Mesopterygoid large and flat, 0.8 time as long as hyomandibular. Pterygoid slender, with fore end not produced into a process. Palatine large, triangular in lateral aspect, and armed with villiform teeth arranged on lower and inner surfaces in a large ovoidal band. Glossohyal wide, spatulate in shape, and marginated in front by a wide cartilaginous band; dorsal surface provided with a wide band of villiform teeth which reaches that cartilage. Urohyal slightly longer than ceratohyal, nearly triangular in shape, somewhat sharply projecting dorso-anteriorly, rounded posteriorly and with moderately expanded lateral wings. Dorsal member of hypophyals strongly inclined inward. Ceratohyal window narrow, occupying the middle of longitudinal channel of ceratohyal. Gill-rakers on first arch $14+7=21$; longest one 0.7 times as long as eye diameter. Main tubercles flattened, irregular in shape, and sporadically scattering on inner side of first arch; each of them thickly coated with minute prickles. Preorbital bone 1.6 times as long as high, somewhat narrow, thickened in its upper half, and deeply notched on posterior margin. First suborbital bone nearly pentagonal in shape, while others much narrowed. Suborbital shelf large in size, and projecting inward on upper margin of second suborbital bone. Suborbital process short but sharp. Posttemporal large in size; supraclavicle widely flattened, with lower end round. Clavicle long, about as long as cranium; upper wing-like portion proportionally small in size;

external and internal shelves intersect at a right angle; the latter for the most part concealed beneath broad posterior extension of the former. Hypercoracoid relatively small, almost quadrangular in form. Hypocoracoid somewhat narrowly elongated and with well-developed postcoracoid process. Lower member of postclavicle somewhat wide, tapering gradually backward and downward. Pelvic girdle 2.3 times as long as wide. Postpelvic process long, with posterior half sharply projecting and divided into a fork interposing a narrow crevice. Interpelvic keel well-developed along entire length of pelvic girdle.

Seriola quinqueradiata TEMMINCK and SCHLEGEL

Seriola quinqueradiata TEMMINCK and SCHLEGEL, Pisces. SIEBOLD's Fauna Japonica, p. 115, pl. 62, fig. 2, 1844-STEINDACHNER and DÖDERLEIN, vol. 3, p. 185, 1884-WAKIYA, Ann. Caranegie Mus., vol. 15, pp. 225–227, pl. 36, fig. 1, 1924.

Material examined:

4 specimens, 430.0–412.5 mm long, at Kuki-ura, Mie Prefecture, 25 November, 1959.

External:

Depth 3.88–4.02; head 3.31–3.50; from tip of snout to origin of first dorsal fin 2.56–2.64; from tip of snout to origin of second dorsal fin 1.98–2.05; from tip of snout to origin of ventral fin 3.42–3.65; from tip of snout to origin of anal fin 1.40–1.56; (numeral represents the ratio of standard length to each item). Snout 2.78–2.96; eye 7.78–8.00; interorbital space 2.98–3.12; upper jaw 2.52–2.58; height of first dorsal fin 7.05–7.23; base of the same 3.80–4.10; height of second dorsal fin 3.00–3.05; base of the same 0.72–0.73; height of anal fin 3.76–3.82; base of the same 0.72–0.74; pectoral 2.10–2.15; ventral 2.20–2.22; from anterior side of anus to origin of anal fin 6.08–6.24; length of caudal peduncle 2.58–2.76; depth of the same 8.50–8.32; ventral spine 4.08–4.10; anal spine 9.40–9.46; ratios of head length to each item. ID. V; IID. I, 30; A. I, 18; P. i, 20.

Body somewhat elongated and moderately compressed. Head conical in shape, with snout somewhat pointed. Outline from tip of snout to origin of dorsal fin approximately linear. Eye relatively small, its diameter 0.38 time the snout length. Maxillary extending beyond anterior margin of pupil; lower jaw as long as upper jaw.

Color in formalin dark greyish brown in dorsal area, gradually becoming paler downward.

Internal:

Material consists of a single specimen, with standard length 430.0 mm and cranial length 87.0 mm.

Rostral length 4.04; diameter of orbit 3.63; postorbital length 2.15; depth 2.35; width 1.85; interorbital width 2.29; ratios between cranial length and respective items.

Cranium much compressed and wider than depth. Preorbital region short, and round at anterior extremity. Mesethmoid-vomerine keel inconspicuously elevated. Vomer crowded with villiform teeth on a cuneiform longitudinal are, extending from fore end of head to median shaft. Superior portion of mesethmoid widened from side to side and slightly projecting forward beyond frontals. Olfactory cavity undeveloped. Lateral expansion of orbital wing of ectethmoid ill-defined, and entirely concealed beneath frontal. Frontal widely extended. Fronto-supraoccipital crest relatively low, its height at the center of brain case 0.27 time the depth of cranium. Supraoccipital 0.75 time the dorsal edge of median crest, and extending as far forward as the center of orbit. Parasphenoid slightly curved upwards in the region beneath sphenotics; ventral surface widely flattened in the region of orbital floor. Myodome widely opens backwards. Sphenotic small in size. Temporal and pterotic crest well-developed, and strongly inclined outwards. Pterotic window absent. Pterotic crest ends in a sharp process, beneath which sharp spine of pterotic projecting. Zygapophyses of exoccipitals of both sides meet each other beneath foramen magnum forming an acute angle. Supramaxillary 0.64 time as long as maxillary, somewhat slender, with upper posterior corner angulated. Ascending process of premaxillary relatively short, about half as long as the premaxillary; articular process thick, semi-circular, not surpassing ascending process, from which it is separated by a "V"-shaped notch. Postmaxillary process short, wide, and with round upper margin. Villiform teeth on lower margin of premaxillary arranged in a narrow band. Those on upper margin of dentary forming again narrower band. Hyomandibular short and stout, 0.4 time the cranial length, with sharp spine at its dorso-posterior corner; anterior two zygapophyses articulated to lateral surface of cranium widely apart. Metapterygoid wide and saddle-like in shape. Metapterygoid lamina undeveloped. Mesopterygoid large, flattened, and about as long as hyomandibular. Pterygoid slender, its fore end not developing into upwardly projeting process. Palatine bent conspicuously outwards in its lower margin, and armed with villiform teeth arranged in a large elliptical band on ventral surface. Preopercle crescentic. Opercle wide, triangular, and slightly longer than interopercle. Glossohyal wide, and provided with a large elliptical band of villiform teeth. Urohyal longer than the distance from fore end of ceratohyal to hind end of epihyal, somewhat navicular in lateral aspect, bluntly pointing dorso-anteriorly, arcuate posteriorly and with lateral wings moderately expanded. Dorsal member of hypophyals strongly inclined inward. Ceratohyal window elongate elliptical, located a little in front of the middle of longitudinal channel of ceratohyal. Gill-rakers on first arch $22+8=30$, the longest of them 1.14 times as long as eye diameter. Main tubercles raised, somewhat ovoidal in shape and thickly covered with minute prickles. Preorbital bone 2.9 times as long as high, strongly narrowed, though thickened in its upper half. First suborbital bone subquadrate, others claviform. Suborbital shelf large in size, and present on the upper margin of second suborbital

bone. Suborbital process short, but sharp. Posttemporal narrowed, but with elongate, relatively broad dorsal branch. Clavicle 0.72 time as long as cranial length; aliform expansion on the upper border proportionally small in size. External and internal shelves makes a right angle, the greater part of the latter being concealed beneath the broad posterior expansion of the former. Hypercoracoid somewhat small in size, irregularly pentagonal in form. Hypocoracoid narrowly elongated, almost triangular in form, and with well-developed postcoracoid process. Lower member of postclavicle somewhat wide, tapering gradually backward and downward. Pelvic girdle wide, 2.4 times as long as width. Postpelvic process long, posterior half sharply produced and forked by the insertion of a narrow crevice. Interpelvic keel well-developed along entire length of pelvic girdle.

Genus *Naucrates* RAFINESQUE

Body nearly cylindrical in form. Scutes entirely absent. Caudal peduncle with longitudinal fleshy keel. Spines on first dorsal short and feeble, and separated one from another without intervention of connecting membrane. Preorbital region wide, short, and lacking in olfactory cavity. Superior portion of mesethmoid slightly projecting anteriorly beyond frontals. Fronto-supraoccipital crest somewhat low. Myodome with rather broad posterior perforation. Zygapophysis of exoccipital for the articulation to atlas joins the fellow of opposite side. Anterior part of parasphenoid has ventral surface widely flattened. Ascending process of premaxillary somewhat short, and distinctly separated from the lower articular process by a "V"-shaped notch. Postmaxillary process wide and semi-circular in outline. Glossohyal much broader anterierly, flabelliform. Lateral wings of urohyal horizontally produced. Epihyal wide, irregularly pentagonal in shape. Preorbital somewhat narrowed, of elongate elliptical form. Suborbital shelf produced inward on the level of upper margin of third suborbital bone. Suborbital process scarcely developed. External shelf of clavicle wider than internal shelf, the two making each other a right angle; anterior shelf better developed. Postcoracoid process triangular. Lower member of postclavicle ensiform. Interpelvic keel well-developed. Last pair of parapophyses connected with each other by a bony bridge. Inferior vertebral foramina absent. Imperfect interneural spines 3 in number; first spine situated in front of first neural spine and the succeeding two inserted between first two neural spines.

Remarks:

This genus distinctly differs from *Seriola* in that the first dorsal fin is provided with short and feeble spines which are not connected one with another by fin membrane, in the flabelliform glossohyal, in the broadness of epihyal, in the horizontally extension of the lateral wings of urohyal and in the better development of the anterior shelf of clavicle.

Naucrates ductor (LINNÉ)

Gasterosteus ductor LINNÉ, Syst. Nat., ed. 10, p. 295, 1758.

Naucrates indicus CUVIER and VALENCIENNES, Nat. Poissons, vol. 9, p. 326, 1833-WAKIYA, Ann. Carnegie Mus., vol. 15, p. 232, pl. 38, fig. 2, 1924.

Naucrates ductor CUVIER and VALENCIENNES, Hist. Nat. Poissons, vol. 8, p. 312, pl. 232, 1831-GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 374, 1860-DAY, Fishes India, p. 229, 1878-JORDAN and EVERMANN, Fishes North and Middle America, Bull. U. S. Nat. Mus., vol. 1, p. 900, pl. 139, 1896-MCCULLOCH, Records Australian Mus., vol. 15, p. 34, pl. 1, 1926-BARNARD, Ann. South African Mus., vol. 21, p. 560, 1927-FOWLER, Mem. Bishop Mus., vol. 10, p. 124, figs. 35–36, 1928-WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, p. 300, figs. 60–62, 1931-FOWLER, Bull. Amer. Mus. Nat. Hist., vol. 70, p. 681, fig. 306, 1936.

Material examined:

1 specimen, 267.5 mm long, at Shimakatsu-ura, Mie Prefecture, 18 September, 1951.
1 specimen, 63.0 mm long, at Owase, Mie Prefecture, 13 November, 1956.

External:

Depth 3.50–3.58; head 3.15–3.74; from tip of snout to origin of first dorsal fin 2.42–3.01; from tip of snout to origin of the second dorsal fin 1.91–2.23; from tip of snout to origin of ventral fin 2.86–3.16; from tip of snout to origin of anal fin 1.50–1.65; (numeral represents the ratio of standard length to each item). Snout 3.44–3.64; eye 4.26–5.10; interorbital space 2.45–3.08; upper jaw 2.96–3.17; height of first dorsal fin 12.50–16.40; base of the same 2.66–3.44; height of second dorsal fin 1.90–2.37; base of the same 0.55–0.80; height of anal fin 2.50–2.77; base of the same 0.98–1.21; pectoral 1.62–1.82; ventral 1.50–1.70; from anterior side of anus to origin of anal fin 4.25–4.77; length of caudal peduncle 3.57–3.67; depth of the same 4.70–4.76; ventral spine 2.86–3.01; anal spine 4.80–7.05; ratios of head length to each item. ID. V; IID. I, 28; A. I, 18; P. i, 18.

Body scarcely compressed, but nearly cylindrical. Snout obtuse, and longer than diameter of eye. Maxillary reaches anterior margin of eye; lower jaw equals to upper jaw in length. First dorsal fin supported by 5 short, feeble spines which are apart one from another. A conspicuous freshy longitudinal ridge present on the sides of caudal peduncle in the specimen with standard length 267.5 mm, but absent in the one with length 63.0 mm.

Color of the larger specimen in formalin dark brownish above, becoming paler below; sides with six inconspicuous blackish bands; fins brownish; pectoral whitish, with dusky outer margin. The smaller specimen grayish brown in dorsal area, gradually becoming lighter downward; black bands on the sides conspicuous; caudal grayish, with a darker blotch at the base and a similar bar on the margin; dorsal, anal and ventral dusky; pectoral whitish as in the larger specimen.

Internal:

Material consists of a single specimen, with standard length 267.5 mm and cranial length 52.5 mm.

Rostral length 5.10; diameter of orbit 2.62; postorbital length 2.28; depth 1.69; width 1.57; interorbital width 2.10; ratios between cranial length and respective items.

Preorbital region of cranium much abbreviated. Mesethmoid-vomerine keel low and rather obscure. Vomer wide and crowded with villiform teeth arranging on ventral surface of its head in a rhomboidal band. Superior portion of mesethmoid widening sidewise and slightly projecting forward beyond frontals. Olfactory cavity undeveloped. Lateral expansion of orbital wing of ectethmoid inconspicuous, and entirely concealed beneath frontal. Fronto-supraoccipital crest somewhat low, thicker anteriorly than posteriorly, making an isosceles triangle in cross section, and elevated at the center of brain case for the height 0.26 time the depth of cranium. Supraoccipital occupies 0.66 time the dorsal edge of median crest, reaching a little behind the middle of orbit. Frontal large and wide. Parasphenoid curved upwards in the region beneath sphenotics, and deeply bifurcated posteriorly; ventral surface wide and flat in the region of orbital floor, laterally bulged into a small protuberance in the region of floor of myodome, and highly keeled in the curved portion. Posterior opening of myodome large and long, about half as long as the distance from the curved portion to posteriormost of basisoccipital. Sphenotic relatively small in size. Temporal and pterotic crests well-developed, and distinctly inclined outwards. Process of pterotic produced posteriorly in ensiform. Zygapophyses of exoccipitals mounting on atlas meet each other beneath foramen magnum narrowly. Supramaxillary more or less short, about half as long as maxillary. Ascending process of premaxillary relatively low, 0.46 time as high as the length of premaxillary; articular process wide, semicircular, not surpassing ascending process, from which it is discriminable by a "V"-shaped notch. Postmaxillary process wide and low. Lower jaw triangular. Upper and lower arms of dentary interposed an angle about 60°. Premaxillary crowded with villiform teeth on lower margin in a narrow band. Dentary similarly dentate on upper margin. Hyomandibular relatively short, 0.52 time the cranial length; anterior two zygapophyses in contact with lateral surface of cranium distinctly apart. Metapterygoid lamina undeveloped. Mesopterygoid relatively large in size, with 0.9 time as long as hyomandibular. Pterygoid slender, lacking upwardly projecting process at fore end. Palatine armed with villiform teeth arranged in a narrow band on the anterior half of ventral border. Opercle wide, and about as long as interopercle. Glossohyal flabelliform, with greatest width subequal to the length; dorsal surface with villiform teeth arranged at the middle in an elliptical band. Urohyal slightly shorter than the distance from fore end of ceratohyal to hind end of epihyal, more or less navicular in shape, and horizontally exserted into lateral wings. Epihyal very wide, and irregularly pentagonal. Ceratohyal window elongate oval, present a little in front of the middle of longitudinal channel of ceratohyal. Gill-rakers on first arch $15 + 4 = 19$, much shorter than the corresponding gill-lamella, and slightly enlarged at distal ends; longest gill-raker 0.54 time as long as eye diameter. Main tubercles on first arch

$9+2=11$, strongly bulged and elliptical in form; each of them densely covered with minute prickles. Preorbital bone rather narrow, 2.16 times as long as wide, with thickened upper border. First suborbital bone quadrate. Second suborbital much reduced in size, resembling a scale. Suborbital shelf large in size, 2.16 times as long as wide, and projecting inward from upper margin of third suborbital bone. Dorsal and ventral branches of posttemporal elongate; protuberance near the bases of the two branches prominent and bearing an aperture of sensory canal at its tip. Clavicle longer than cranial length; upper wing-like portion proportionally small in size; external and internal shelves making a right angle, the greater part of the latter concealed beneath far broader posterior expansion of the former; anterior shelf strongly expanded. Hypercoracoid quadrangular, small in size. Hypocoracoid narrow, elongate, nearly triangular; postcoracoid process forming a broader triangle. Lower member of postclavicle tapering gradually backward and downward. Pelvic process wide, 2.66 times as long as wide. Postpelvic process long, 0.37 time as long as pelvic girdle, and forked in the rear interposing a narrow crevice. Interpelvic keel well-developed extending entire length of pelvic girdle.

Remarks:

Fully maturated ovary was observed in the specimen 267.5 mm long. From the digestive tube of this specimen three individuals of *Engraulis japonica* (Houttuyn) and numerous fragments of shrimps were detected.

Wakiya (1924) assigns the specimens discoverable in the seas around Japan to *Naucrates indicus* Cuvier and Valenciennes, saying this is distinguishable from *N. ductor* (Linné) by compression of body, by the diameter of eye and by the length of ventral fin relative to the same of pectoral fin. The present author is of the opinion that the two are synonymous, since these differences do not appear to him to be sufficient to separate them.

Genus *Elagatis* Bennet

Body long, slender, and slightly compressed. Second dorsal and anal with a single fin-let detached from others. Scute entirely undeveloped. Cranium wide, somewhat depressed. Preorbital region wide and short. Olfactory cavity shallow, overlapped by forward elongation of frontal. Fronto-supraoccipital crest low. Myodome with broad posterior perforation. Zygapophysis of exoccipital for the articulation to atlas joins the fellow of opposite side at the tip. Parasphenoid somewhat widely flattened on ventral surface in its anterior part. Ascending process of premaxillary relatively long, and distinctly separated from the lower articular process by a "V"-shaped notch; postmaxillary process low, wide, and semi-circular in shape. Pterygoid slender, without upwardly projecting process at the fore end. Urohyal has a medio-ventral longitudinal crest in addition to a pair of broadly expanded lateral wings. Upper half of preorbital bone rugose, and somewhat thickened. Sub-

orbital shelf narrow. Suborbital process absent. Postcoracoid process strongly projecting, somewhat spatulate in form. Lower member of postclavicle wide, tapering gradually backward and downward. Interpelvic keel well-developed. Last parapophyses of two sides combined with each other by bony bridge. Inferior vertebral foramina entirely absent. Imperfect interneural spines 3 in number; first of them in front of first neural spine and the succeeding two between every two of the first three neural spines.

Remarks:

Though the present genus resembles *Seriola*, it differs in the possession of an isolated fin-let behind the second dorsal and the anal fin, in the shallow olfactory cavity roofed by the anterior elongation of the frontal, in the absence of suborbital process and in the urohyal furnished with the medio-ventral longitudinal crest.

Elagatis bipinnulata (Quoy and Gaimard)

Seriola bipinnulata Quoy and Gaimard, Voy. Uranie, Zool., vol. 1, p. 363, pl. 61, fig. 3, 1824.

Elagatis bipinnulata Bennet, Narrative Whaling Voyage, vol. 2, p. 283, 1840-Meek and Bollman, Proc. Acad. Sci. Phila., p. 42, 1890-Jordan and Evermann, Fishes North and Middle America, vol. 1, p. 906, 1896-Jordan and Evermann, Bull. U. S. Fish. Comm., vol. 23, part 1, p. 185, 1905-Wakiya, Ann. Carnegie Mus., vol. 15, p. 233, pl. 37, fig. 2, 1924-Oshima, Philippine Jour. Sci., vol. 26, p. 357, 1925-Weber and De Beaufort, Fishes Indo-Australian Archipelago, vol. 6, p. 293, fig. 58, 1931.

Material examined:

2 specimens, 224.5–220.0 mm long, at Shimakatsu-ura, Mie Prefecture, 18 September, 1951.
1 specimen, 405.0 mm long, at Nikishima, Mie Prefecture, 5 April, 1958.

External:

Depth 3.83–4.21; head 3.88–4.25; from tip of snout to origin of first dorsal fin 2.81–3.02; from tip of snout to origin of second dorsal fin 2.12–2.16; from tip of snout to origin of ventral fin 1.61–1.64; from tip of snout to origin of anal fin 3.65–3.70; (numeral represents the ratio of standard length to each item). Snout 2.46–2.86; eye 4.00–4.27; interorbital space 2.82–2.91; upper jaw 2.78–3.09; height of first dorsal fin 5.70–6.45; base of the same 2.67–2.68; height of second dorsal fin 2.26–2.37; base of the same 0.59–0.64; height of anal fin 2.52–2.37; base of the same 0.98–1.02; pectoral 1.62–1.94; ventral 1.78–1.87; from anterior side of anus to origin of anal fin 5.67–6.30; depth of caudal peduncle 4.37–5.05; length of the same 1.80–2.07; ventral spine 3.1; anal spine 6.23; ratios of head length to each item. ID. VI; IID. I, 25; A. I, 17; P. i, 19–20.

Body fusiform, slightly compressed. Snout somewhat pointed. Maxillary not reaching anterior of eye; lower jaw slightly longer than upper jaw.

Color in formalin brown above, lighter below; first dorsal fin brown; ventral fin blackish; other fins grayish; posterior margin of caudal fin darker.

Internal:

Material consists of a single specimen, with standard length 405.0 mm and cranial length 83.0 mm.

Rostral length 3.46; diameter of orbit 3.16; postorbital length 2.42; depth 2.56; width 2.08; interorbital width 2.81; ratios between cranial length and respective items.

Mesethmoid-vomerine keel somewhat conspicuous, but low. Vomer crowded with villiform teeth on a cuneiform longitudinal area, extending from the fore end to the middle. Superior portion of mesethmoid widened from side to side and projecting forward a little beyond frontals. Olfactory cavity wide but shallow, and roofed by anterior elongation of frontal. Lateral expansion of ectethmoid inconspicuous, and concealed beneath frontal nearly completely. Ventral surface of parasphenoid broad and flattened in the region of orbital floor, obtusely convex in the region of myodome floor, though with a shallow median groove, and highly keeled in the region beneath sphenotics. Fronto-supraoccipital crest low, its height at the center of brain case 0.2 time the cranial depth. Pterotic window absent. Pterotic crest ends in a sharp process, beneath which it accompanies a sharp, ensiformed posteriorly projecting spine. Zygapophyses of exoccipitals mounting on atlas come in contact with each other beneath foramen magnum. Myodome widely open backwards. Supramaxillary slender and elongate, 0.7 time as long as maxillary. Ascending process of premaxillary about half as long as premaxillary; articular process not attaining higher than ascending process; the two interposing a "V"-shaped notch; postmaxillary process short, wide, and semicircular in form. Lower margin of premaxillary and upper margin of dentary crowded with villiform teeth which a band, wider anteriorly and gradually narrower posteriorly. Hyomandibular with a sharp spine on its dorso-posterior corner; anterior two zygapophyses articulated to lateral surface of cranium distinctly apart. Metapterygoid lamina undeveloped. Mesopterygoid large, 1.08 times as long as hyomandibular. Pterygoid slender, without process at its fore end. Villiform teeth on palatine arranged in a narrow band on anterior half of lower surface. Glossohyal relatively long, spatulate in shape, and armed in its posterior half with villiform teeth set on a longitudinal narrow band. Urohyal shorter than the distance from fore end of ceratohyal to rear end of epihyal, and furnished with a medio-ventral longitudinal crest besides with horizontally expanded lateral wings. Ceratohyal window elongate oval in shape, lying a little in front of the middle of longitudinal groove of ceratohyal. Interhyal small, rod-like in form, and 0.3 time as long as glossohyal. Gill-rakers on first arch $16+7=23$; main tubercles on the same $12+4=16$. Preorbital narrow, 4.1 times as long as wide; its upper half somewhat thickened and rugose on surface. Suborbital shelf narrow. Suborbital process undeveloped. External and internal shelves make a right angle, the latter for the most part concealed beneath broad posterior expansion of the former. Postcoracoid process spatulate in form, strongly projecting, and forming a deep concavity with the lowermost actinost. Upper member of

postclavicle large in width, and more or less reniform. Lower member also wide, but tapering gradually backward and downward. Pelvic girdle 2.4 times as long as wide. Postpelvic process elongate, slightly forked posteriorly. Interpelvic keel well-developed.

Remarks:

In the interior of the digestive tract of the specimen 224.5 mm long, vertebral column of three fishes, two crabs and numbers of fragments of shrimps were discovered.

Chorineminae

Body less high, much compressed. Scales rudimentary, and imbedded under the skin. Lateral line devoid of scutes. Preorbital region short. Olfactoly cavity absent. Fronto-supraoccipital crest somewhat low. Myodome with a large posterior perforation. Epiotics of both sides come in contact with each other by a long line in the interior of cranium. Zygapophysis of exoccipital joins the fellow of opposite side beneath foramen magnum. Supramaxillary poorly developed or entirely absent. Premaxillay non-protractile; postmaxillary process undeveloped. No interosseous space between dorsal arm of dentary and upper margin of articular. Pterygoid slender, without anterior process. Branchiostegal rays in 8. Suborbital shelf projecting inward from upper margin of third suborbital bone. Interpelvic keel well-developed. Caudal vertebrae in 16. Last parapophyses of two sides combined with each other by a bony bridge. Inferior vertebral foramina absent. Imperfect interneural spines 3 in number; first spine in front of first neural spine and the succeeding two inserted between every two of the first three neural spines. Both first haemal spine and first interhaemal spine large and stout, firmly united together, to forming the posterior border of abdominal cavity.

Remarks:

The Chorineminae is distinct from other subfamilies of the Carangidae in having non-protractile premaxillary, in the lack of postmaxillary process, in the absence of interosseous space between the dorsal arm of the dentary and the upper margin of the articular, and in being the branchiostegal rays 8 in number.

Genus *Chorinemus* CUVIER and VALENCIENNES

Body somewhat elongate, but much compressed. Scales rudimentary, and imbedded under skin. Scute lacking. Mesethmoid with superior portion widening sidewise and slightly projecting beyond frontals. Fronto-supraoccipital crest low. Myodome with wide posterior perforation. Zygapophysis of exoccipital joins the fellow of opposite side. Supramaxillary much reduced in size. Maxillary slender, elongated. Premaxillary non-protractile, with short ascending and articular pro-

cesses, and without postmaxillary process. Lower jaw narrow; no interosseous space between dorsal arm of dentary and upper margin of articular. Interopercle much smaller than opercle. Urohyal low, with moderately expanding lateral wings. Preorbital narrow, and thickened in its upper margin. Suborbital shelf circular in form. Upper wing-like portion of clavicle proportionally small in size; external and internal shelves making an angle of about 60°. Hypocoracoid widely expanded. Pelvic girdle wide and short. Interpelvic keel well-developed. Caudal vertebrae in 16. Last pair of parapophyses combined by a bony bridge. Inferior vertebral foramina absent. Imperfect interneural spines 3 in number, first spine in front of first neural spine and the succeeding two inserted between every two of the first three neural spines.

Chorinemus orientalis **TEMMINCK and SCHLEGEL**

Chorinemus orientalis TEMMINCK and SCHLEGEL, Fauna Japonica, Poiss., p. 106, pl. 57, fig. 1, 1844-DUNCKER and MOHR, Naturh. Mus. Hamburg, Mitteil., vol. 44, p. 80, 1920.

Scomberorides orientalis WAKIYA, Ann. Carnegie Mus., vol. 15, p. 237, pl. 38, fig. 4.

Material examined:

1 specimen, 106.0 mm long, at Owase fish market, Mie Prefecture, 31 October, 1951.
1 specimen, 177.0 mm long, at Kuki-ura, Mie Prefecture, September, 1959.

External:

Depth 3.34–3.53; head 4.46–4.92; from tip of snout to origin of first dorsal fin 3.42–3.54; from tip of snout to origin of second dorsal fin 2.10–2.12; from tip of snout to origin of ventral fin 3.72–4.54; from tip of snout to origin of anal fin 2.04–2.08; (numeral represents the ratio of standard length to each item). Snout 3.05–3.50; eye 3.66–3.84; interorbital space 3.36–3.05; upper jaw 1.84–1.86; height of first dorsal fin 4.23–4.76; base of the same 1.25–1.44; height of second dorsal fin 1.56–1.64; base of the same 0.84–0.54; height of anal fin 1.86–1.89; base of the same 0.47–0.54; pectoral 1.56–1.64; ventral 1.76; from anterior side of anus to origin of anal fin 1.56–1.98; length of caudal peduncle 2.77–3.26; depth of the same 3.79–4.40; ventral spine 3.27–3.40; anal spine 3.97; ratios of head length to each item. ID. VII; IID. I, 20; A. I, 18; P. i, 18.

Snout pointed, slightly longer than diameter of eye. Maxillary extending to posterior border of eye. Scales lanceolate, with round end.

Color in formalin greyish brown above, lighter below; two dorsal fins grayish; top of second dorsal fin black; lobes of caudal fin somewhat blackish; anal and paired fins whitish.

Internal:

Material consists of a single specimen, with standard length 177.0 mm and cranial length 27.5 mm.

Rostral length 6.12; diameter of orbit 2.62; postorbital length 2.00; depth 1.77;

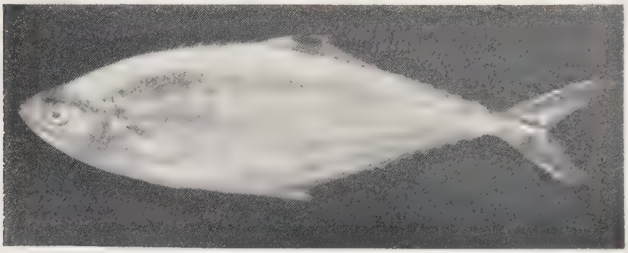

Fig. 50. *Chorinemus orientalis* TEMMINCK and SCHLEGEL, 177.0 mm in standard length.

width 2.35; interorbital width 2.75; ratios between cranial length and respective items.

Preorbital region of cranium much shortened; dorsal border from fore end of frontal to vomer steep, and nearly perpendicular to orbital floor. Mesethmoid-vomerine keel inconspicuous. Vomer armed on antero-ventral surface with villiform teeth arranged in a circular band, and provided on mid-ventral surface of its median shaft with a shallow longitudinal groove. Superior portion of mesethmoid widened from side to side and slightly projecting forward beyond frontals. Olfactory cavity undeveloped. Fronto-supraoccipital crest low, thickened in its frontal region, making an isoscele triangle in cross section, and with height at the center of brain case 0.12 time the cranial depth. Supraoccipital covers 0.65 time the dorsal edge of median crest, reaching a little behind the middle of orbit, and projecting posteriorly into a sharp process. Parasphenoid curved upwards in the region beneath sphenotics; ventral surface narrow, flattened and provided with shallow mid-ventral groove in the region of orbital floor, scarcely keeled in the curved portion, and almost flattened in the region of myodome floor. Sphenotic relatively large in size, with lateral orbital wing deeply concave on its lower edge in lateral aspect. Temporal crest low, but well-developed, and perpendicular to the dorsal surface. Posterior opening of myodome wide and large. Zygapophyses of exoccipitals meet each other beneath foramen magnum. Supramaxillary much reduced in size, 0.12 time as long as maxillary. Maxillary narrowly elongate, stick-like with an enlarged tip in shape. Ascending process of premaxillary low, 0.25 time as high as the length of premaxillary; articular process not surpassing ascending process, and indistinctly separated from the latter; postmaxillary process undeveloped. Lower jaw very narrow; dorsal arm of dentary and upper margin of articular interposing no interosseous space. Lower margin of premaxillary fringed with villiform teeth arranged in a narrow band; those on upper margin of dentary in two series; outer series more thickly crowded with teeth bending strongly outward. Hyomandibular relatively short, 0.47 time the cranial length; anterior two zygapophyses widely apart from each other. Metapterygoid lamina undeveloped. Mesopterygoid ovate, large in size, 0.88 time as long as hyomandibular, and crowded with villiform teeth forming an oblong oval band on ventral surface. Pterygoid

slender, angularly curved, and without upwardly projecting process at its fore end; length from this curving point to fore end of palatine 1.16 times that of hyomandibular. Palatine slender, and armed inside the ventral edge with villiform teeth arranged on a somewhat wide band. Interopercle small in size, much shorter than opercle. Glossohyal elongate ovoidal in shape, and armed on entire dorsal surface with villiform teeth. Urohyal with length smaller than that from fore end of ceratohyal to rear end of epihyal, linear along dorsal border, and moderately expanded laterally on its ventral edge. Ceratohyal window slit-like. Gill-rakers on first arch $17+7=24$; longest of them 0.7 time as long as eye diameter. Main tubercles on the same $25+4=29$, inconspicuous bulges of irregular shape and thickly coated with tiny prickles. Preorbital bone narrow, 3.3 times as long as high, and thickened on its upper margin. First suborbital bone wide, and trapezoid; second much reduced in size, and scale-like in shape; third longest of all, gradually increasing backwards in its width; fourth rod-like; fifth rudimentary. Suborbital shelf more or less circular and projecting inward from upper margin of third suborbital. Clavicle long, and with length 0.91 time as long as the cranium; upper aliform end very small in size; external and internal shelves at an angle of 60°. Hypercoracoid small in size, triangular. Hypocoracoid wide. Upper postclavicle lamellar and crescentic. Lower postclavicle rib-like except having a lamellar region at upper end. Pelvic girdle 2.2 times as wide as long. Postpelvic process so long as to reach 0.35 time the length of pelvic girdle, and with posterior half not forked. Interpelvic keel well-developed.

Trachinotinae

Body oblong, much compressed, and bearing small cycloid scales. Scute undeveloped. Preorbital region much shortened. Olfactory cavity absent. Superior portion of mesethmoid projecting far beyond frontals to form a crescentic concavity. Fronto-supraoccipital crest somewhat highly elevated. Zygapophysis of exoccipital joins the fellow of opposite side at the tip. Posterior pore of myodome small. Posterior part of parasphenoid greatly expanded sidewise along ventral border, forming a broad, flattened plate. Basioccipital with a pair of lateral process on ventral surface. Supramaxillary absent. Premaxillary protractile; ascending process somewhat long; postmaxillary process thick, semi-circular. Pterygoid slender, with fore end truncate. Suborbital shelf projecting inward from upper margin of third suborbital bone, and unaccompanied with suborbital process. Ventral branch of posttemporal much reduced in size, projecting only slightly. Interpelvic keel present. Caudal vertebrae 14 in number. Last two pairs of parapophyses combined together by a bony bridge. Inferior vertebral foramina entirely absent. Imperfect interneural spines 3 in number; first of them in front of first neural spine and the succeeding two interposed between consecutive two of first three neural spines. Both of first haemal and interhaemal spines large and stout, coalesced with each

other to form a curved posterior boundary of abdominal cavity.

Remarks:

The Trachinotinae is clearly discriminated from all other subfamilies of Carangidae in the absences of the supramaxillary, in the expansion of the parasphenoid along the ventral edge of its posterior part into a broad and flattened plate, in having a pair of lateral processes on the basioccipital, and in the ventral branch of posttemporal being much reduced in size.

Genus *Trachinotus* LACÉPÉDE

Snout obtuse and short. First dorsal fin composed of a few, short, isolated spines. Scutes entirely absent. Preorbital region of cranium much shortened, with dorsal contour nearly vertical to orbital floor. Olfactory cavity undeveloped. Fronto-supraoccipital crest somewhat highly elevated. Supramaxillary absent. Ascending process of premaxillary somewhat elongate, and distinct from lower articular process owing to the insertion of "V"-shaped notch between them. Pterygoid slender, neither enlarged at fore end nor produced. Lateral wings of urohyal slightly extened in horizontal direction. Preorbital bone narrow. Suborbital shelf rounded. Suborbital process lacking. Posttemporal with ventral branch rudimentary, projecting only slightly. Upper postclavicle narrow, somewhat navicular in shape. Lower postclavicle ensiform, tapering gradually backward and downward. Interpelvic keel present. Last two pairs of parapophyses connected together by a bony bridge. Inferior vertebral foramina entirely absent. Imperfect interneural spines 3 in number; first of them in front of first neural spine and the succeeding two interposed between successive two of the first three neural spines.

Trachinotus bailloni (LACÉPÈDE)

Caesiomorus bailloni LACÉPÉDE, Hist. Nat. Poissons, vol. 3, p. 93, pl. 3, fig. 1, 1802.

Caesio quadripunctatus RÜPPELL, Atlas Reise Nordl. Afrika Fische, p. 90, pl. 24, fig. 1, 1828.

Trachinotus bailloni CUVIER and VALENCIENNES, Hist. Nat. Poissons, vol. 8, p. 431, 1831.

Trachinotus quadripunctatus CUVIER and VALENCIENNES, Hist. Nat. Poissons, vol. 8, p. 434, 1831.

Trachinotus bailloni GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 484, 1860-GÜNTHER, Fische der Südsee, vol. 2, p. 139, 1876-WAKIYA, Ann. Carnegie Mus., vol. 15, p. 219, 1924.

Trachinotus bailloni DAY, Fishes India, p. 233, pl. 51 A, fig. 4, 1878.

Trachinotus bailloni EVERMANN and SEALE, Bull. U. S. Bur. Fisheries, vol. 26, p. 66, 1907-OSHIMA, Philippine Jour. Sci. vol. 26, p. 407, 1925-FOWLER, Mem. Bishop Mus., vol. 10, p. 152, 1928.

Trachynotus quadripunctatus WAKIYA, Ann. Carnegie Mus., vol. 15, p. 220, 1924.

Trachynotus cuvieri WAKIYA, Ann. Carnegie Mus., vol. 15, p. 220, 1924.

Trachinotus bailloni WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, p. 288, 1931-HERRE, Field Mus. Nat. Hist., Zool. Ser., vol. 21, p. 117, 1936.

Material examined:

8 specimens, Nos. 6563, 7854, 8516, 12485, 21982, 33918, 40302, 40303 (Collection in Department of Zoology, Faculty of Science, Tokyo University), 130.0–80.0 mm long, date and locality unknown.

2 specimens, 148.0–140.0 mm long, at Toba, Mie Prefecture, 4 February, 1961.

External:

Depth 2.1–2.5; head 3.31–3.83; from tip of snout to origin of first dorsal fin 2.73–3.04; from tip of snout to origin of second fin 1.76–1.98; from tip of snout to origin of ventral fin 3.34–4.28; from tip of snout to origin of anal fin 1.86–1.98; (numeral represents the ratio of standard length to each item). Snout 3.61–4.40; eye 3.89–4.44; interorbital space 2.62–3.06; upper jaw 2.36–2.73; height of first dorsal fin 4.12–5.10; base of the same 1.55–2.06; height of second dorsal fin 0.71–1.17; base of the same 0.68–0.83; height of anal fin 0.73–1.15; base of the same 0.66–0.83; pectoral 1.36–1.60; ventral 1.88–2.42; from anterior side of anus to origin of anal fin 1.79–2.52; length of caudal peduncle 1.95–2.40; depth of the same 2.75–3.22; ventral spine 3.92–4.74; ratios of head length to each item. ID. VI; IID. I, 24–21; A. I, 24–21; P. i, 17–16.

Body oblong, much compressed. Snout obtuse. Maxillary extends to frontal border of pupil; lower jaw slightly shorter than the upper. Anterior nostril much smaller than the posterior, situating in the midway snout end and fore margin of eye. Lateral line scarcely curved and not armed with scutes. First dorsal fin with 6 short, isolated spines. Fore ends of second dorsal and anal fins falcate.

Color in formalin brown above, growing paler downward; 4 small black spots on lateral line; the first beneath fore end of first dorsal fin, the second beneath fifth ray of the same, the third beneath sixth ray of second dorsal fin, the fourth beneath sixteenth ray of the same.

Fig. 51. *Trachinotus bailloni* (LACÉPÈDE), 154.0 mm in standard length.

Internal:

Material consists of a single specimen, with standard length 144.0 mm and cranial length 31.0 mm.

Rostral length 5.65; diamater of orbit 2.82; postorbital length 2.00; depth 1.59; width 2.06; interorbital width 2.59; ratios between cranial length and respective items.

Preorbital region of cranium short, showing its dorsal outline steep and nearly vertical to orbital floor. Mesethmoid-vomerine keel low, but conspicuous. Mesethmoid projecting forward beyond frontals in its superior portion to form a crescentic sinus. Olfactory cavity cavity undeveloped. Fronto-supraoccipital crest more or less highly raised, 0.28 time as high as the depth of cranium at its middle. Supraoccipital occupying 0.88 time the length of dorso-median crest, extending as far forward as the fore end of orbit. Sphenotic large in size. Parasphenoid curved upwards in the region beneath sphenotics; ventral surface narrow and flat in the region of orbital floor, but greatly expanded into an oval flat plate in the region of floor of myodome, and somewhat sharply keeled in the curved portion. Myodome with a small, oval posterior opening. Temporal crest begins in the region just above anterior boundary of orbit. Pterotic crest arises from in the region above posterior boundary of orbit, and blunt at the rear end. Pterotic window absent. Pterotic without process posteriorly projecting beyond the hind end of pterotic crest. Zygapophyses of exoccipitals meet each other at a narrow angle beneath foramen magnum. Basioccipital with a pair of lateral processes on its ventral surface. Supramaxillary absent. Ascending process of premaxillary somewhat elongate, a half as high as the length of premaxillary; articular process much shorter than ascending process, from which it is distinguishable by a "V"-shaped notch. An angle interposed between upper and lower armes of dentary about 45°. Upper margin of dentary and lower margin of premaxillary crowded with villiform teeth forming a band. Hyomandibular narrow and long, half as long as cranium; anterior two zygapophyses distinctly apart from each other. Metapterygoid lamina undeveloped. Mesopterygoid relatively slender, with fore end neither expanded nor upwardly projecting. Palatine slender, with a ventral marginal band crowded with villiform teeth. Glossohyal spatulate and toothless. Urohyal about as long as the distance from fore end of ceratohyal to hind end of epihyal, and slightly expanded laterally. Ceratohyal window slit-like. Gill-rakers on first arch $16+6=22$; the longest of them a half as long as eye diameter, and as long as the corresponding gill-lamella. Main tubercles on the same $15+7=22$, well elevated, nearly ovate, and thickly crowded with minute prickles on the surface. Preorbital bone 2.4 times as long as high, narrow, but with thickened upper margin. Suborbital shelf circular, arising from upper margin of third suborbital bone. Suborbital process absent. Dorsal branch of posttemporal moderately long, though ventral one rudimentary, remaining to projecting only a little from the bone. Clavicle about as long as cranium; upper wing-like portion relatively small in size, resembling a triangle in shape; external and internal shelves making an angle of 60°. Upper postclavicle very narrow; lower one of lancet form. Pelvic girdle narrow but long, 3.8 times as long as wide. Postpelvic process short, 0.15 time as long as pelvic girdle, and with a slight posterior bifurcation. Interpelvic keel distinct.

Remarks:

Wakiya (1924) recorded *Trachinotus cuvieri* Wakiya and *T. quadripunctatus* (Rüppell) besides the present species from the neighboring waters of Japan, differentiating this from those on the basis of the differences in the head, pectoral, ventral, and caudal lengths and in the numbers of soft rays of dorsal and anal fins. The present author considers all of those species as synonymous with one another, since the above named appear to him insufficient for differentiating those.

Trachinotus ovatus (Linné)

Gasterosteus ovatus Linné, Syst. Nat. vol. 1, p. 490, 1758.

Centronotus ovalis Lacépède, Hist. Nat. Poissons, vol. 3, p. 309, 1798.

Trachinotus falcatus Lacépède, Hist. Nat. Poissons, vol. 3, p. 79, 1798.

Trachinotus ovatus Günther, Cat. Fishes British Mus., vol. 2, p. 481, 1860-Günther, Fische der Südsee, p. 139, 1873-Day, Fishes India, p. 234, pl. 51 B, fig. 2, 1896-Fowler, Jour. Acad. Nat. Sci. Phila., vol. 12, p. 513, 1906-Jordan and Seale, Bull. U. S. Bur. Fisheries, vol. 26, p. 235, 1906-Jordan and Richardson, Mem. Carnegie Mus., vol. 4, p. 180, 1909-Jordan, Tanaka and Snyder, Jour. Coll. Sci. Tokyo, vol. 33, p. 131, 1931-Oshima, Philippine Jour. Sci., vol. 26, pp. 409–410, 1925.

Material examined:

2 specimens, Nos. 27161, 26976 (Collection in Department of Zoology, Faculty of Science, Tokyo University), 74.0–67.0 mm long, at Tokyo fish market, date unknown.

1 specimen, 226.0 mm long, at Persian Gulf, March, 1957, collected by Dr. Reizo Ishiyama, Professor of Shimonoseki College of Fisheries.

External:

Depth 1.60–1.80; head 3.08–3.58; from tip of snout to origin of first dorsal fin 2.47–2.56; from tip of snout to origin of second dorsal fin 1.68–1.72; from tip of snout to origin of ventral fin 2.64–3.27; from tip of snout to origin of anal fin 1.68–1.69; (numeral represents the ratio of standard length to each item). Snout 4.21–4.67; eye 3.54–3.82; interorbital space 2.17–2.67; upper jaw 2.93–3.29; height of first dorsal fin 5.60–7.41; base of the same 1.83–2.24; height of second dorsal fin 0.78–1.05; base of the same 0.71–0.86; height of anal fin 0.93–1.18; base of the same 0.72–0.98; pectoral 1.23–1.57; ventral 1.95–2.52; from anterior side of anus to origin of anal fin 1.75–2.82; length of caudal peduncle 2.73–4.34; depth of the same 2.93–3.53; ventral spine 3.87–4.80; anal spine 4.27–7.88; ratios of head length to each item. ID. VI; IID. I, 20–19; A. I, 18–16; P. i, 18.

Body tall, much compressed, oval in shape. Dorsal border descending gradually from origin of first dorsal fin to upper margin of eye, from which it rapidly inclines towards tip of snout until it becomes nearly vertical to longitudinal axis of body. Snout obtuse, slightly shorter than diameter of eye. Mouth only narrowly gaping; maxillary extends beyond anterior border of eye, but never reaches frontal border of pupil; lower jaw only slightly longer than upper. Jaws, vomer and palatines toothless. Anterior and posterior nostrils close to each other; posterior one larger, ovate, 2.3 times as large as anterior one in longitudinal diameter. Gill-rakers on first arch $8+4=12$, short but stout; the longest of them 0.2 time as long as the

eye diameter and 0.3 time as long as the corresponding gill-lamella. First dorsal fin constructed by 6 short, isolated spines. Anterior rays of second dorsal and anal fins elongate, falcate in shape.

Color in formalin brownish grey above, lighter below.

Fig. 52. *Trachinotus ovatus* (LINNÉ), 226.0 mm in standard length.

Internal:

Anatomizing the material was impossible on account of that only a single specimen was available.

Caranginae

Body oblong ovate or subcylindrical in shape, strongly or feebly compressed, and covered with small cycloid scales. Scutes vary in their development, being found on the whole length of lateral line or only on its posterior linear region. Premaxillary protrusible; postmaxillary process always present. Suborbital lamina in contact with first and second suborbital bones or with first alone. Suborbital process distinct. Both dorsal and ventral branches of posttemporal well produced forward. Caudal vertebrae 14–15 in number. Imperfect interneural spines 3 in number; first spine in front of first neural spine and the others inserted between first two neural spines.

Key to genera

1a Ascending process of premaxillary not reaching beyond articular process.
 2a Inferior vertebral foramina distinct.
  3a Myodome with distinct posterior perforation.
   4a Mesethmoid-vomerine keel indistinct; ascending process shorter than premaxillary.
    5a Postmaxillary process relatively short, with upper margin round.
     6a Suborbital process long, compressed into a plate; pelvic girdle not com-

pressed; interpelvic keel moderately developed; postpelvic process projecting dorso-posteriorly············***Caranx***

6b Suborbital process rod-like; pelvic girdle much compressed; interpelvic keel well-developed; postpelvic process projecting vertically in relation to pelvic girdle············***Atropus***

5b Postmaxillary process relatively large in size, subtriangular.

7a Last parapophyses with inferior vertebral foramina; urohyal not very wide; orbital wing of ectethmoid moderately projecting outwards ············***Citula***

7b Last three parapophyses with inferior vertebral foramina urohyal very wide; orbital wing of ectethmoid round in outline, continuing gracefully to frontal without forming angle············***Alectis***

4b Mesethmoid-vomerine keel strongly elevated, plate-like in appearance; ascending process of premaxillary very high, about as long as premaxillary.

8a Mesethmoid-vomerine keel not thin; olfactory cavity wide and shallow; parasphenoid highly keeled on ventral surface in the region of orbital floor; rostral cartilage elongate, oval in shape, not compressed; suborbital lamina large, closely adjoining upper margin of first and second suborbital bones; suborbital process hardly developing; interpelvic keel present············***Gnathanodon***

8b Mesethmoid-vomerine keel a thin plate; olfactory cavity narrow and deep; ventral surface of parasphenoid narrow and flat in the region of orbital floor; rostral cartilage triangular in shape, much compressed; suborbital lamina small, in contact with upper margin of first suborbital bone; suborbital process long; interpelvic keel absent···***Selaroides***

3b Myodome close or narrowly open backward.

9a Inferior vertebral foramina present in last three parapophyses.

10a Second, third and fourth haemal spines with disc-like enlargement on anterior margin············***Uraspis***

10b Haemal spine without disc-like enlargement on anterior margin ············***Carangoides***

9b Inferior vertebral foramina present in last two parapophyses ············***Atule***

2a Inferior vertebral foramina absent from haemal spine and parapophysis.

11a Zygapophysis of exoccipitals meeting each other; fronto-supraoccipital crest high; lateral wing of urohyal slightly expanded; suborbital process somewhat elongate, compressed into a plate ············***Kaiwarinus***

11b Zygapophyses of exoccipitals slightly apart from each other; fronto-supraoccipital crest somewhat high; lateral wing of urohyal much expanded; suborbital process rod-like············***Longirostrum***

1b Ascending process of premaxillary distinctly shorter than articular process.

12a Urohyal shorter than hyoid body.

13a Mesethmoid-vomerine keel highly eleveted, plate-like; last three pairs of parapophyses combined by bony bridges; inferior vertebral foramina present at the base of first haemal spine .... ***Trachurops***

13b Mesethmoid-vomerine keel moderately developed; last two pairs of parapophyses combined by bony bridges; inferior vertebral foramina entirely absent............ ***Trachurus***

12b Urohyal about as long as, or slightly longer than hyoid body .... ***Decapterus***

Genus *Caranx* LACÉPÈDE

Body somewhat high, moderately compressed. Scutes present only on straight portion of lateral line. Breast scaly. Preorbital region of cranium short, without olfactory cavity. Fronto-supraoccipital crest high. Supraoccipital extends on the crest as far forward as the middle of orbit. Myodome with a distinct posterior opening. Zygapophyses of exoccipitals meet each other beneath foramen magnum. Ventral surface of parasphenoid highly keeled in region of orbital floor. Ascending process of premaxillary slightly surpassing articular process; the two somewhat indistinctly distinguishable; postmaxillary process very short and small. Mesopterygoid small in size, with flat dorsal surface. Pterygoid wide and produced at the dorso-anterior corner into an elongated process. Main tubercle generally low and with tiny prickles, though somewhat bulged and with a number of longer, stouter ones on anterior side. Preorbital bone flat and wide. Suborbital process compressed into a shape of a razor. External and internal shelves of clavicle making together a right angle. Lower postclavicle rib-like appearance. Interpelvic keel present only in posterior half of pelvic girdle. Last three pairs of parapophyses connected together by bony bridges. Inferior vertebral foramina distinct in last three parapophyses and first haemal spine.

Key to species

1a Cranium relatively low; two arms of dentary making an angle of 45°; articular with dorsal process feeble, not surpassing one third its own height.

2a Urohyal low, about 3.1 times as long as high, lateral wings well expanding; metapterygoid wide, about as wide as long at its widest region; palatine wide and stout............ ***Caranx hippos***

2b Urohyal higher, twice as long as high, lateral wings moderately expanding; metapterygoid not very wide, its greatest width less than the length; palatine somewhat slenderly projecting............ ***Caranx sexfasciatus***
Caranx xanthopygus

1b Cranium relatively high; two arms of dentary interposing an angle larger than 45°; process at the dorsal angle of articular long, extending beyond one third the height of articular.

3a Upper fore border of mesethmoid distinctly sinuous, exhibiting a "V"-shaped

appearance in dorsal view; anterior free margin of metapterygoid nearly straight; lower edge of dentary with a circular notch······***Caranx ishikawai***

3b Upper fore border of mesethmoid only slightly concave; anterior free margin of metapterygoid not straight but slightly concave; lower edge of dentary without notch.

4a Glossohyal relatively narrow, 3.4 times as long as wide, and fringed by broad cartilaginous band along fore margin···········***Caranx melampygus***

4b Glossohyal relatively wide, 2.5 times as long as wide, fringed by narrow cartilaginous band on fore margin···········***Caranx bixanthopterus***

Caranx hippos (LINNÉ)

Scomber hippos LINNÉ, Syst. Nat., ed. 12, p. 494, 1766.

Scomber carangus BLOCH, Natuges. Ausland, Fische, vol. 7, p. 69, pl. 350, 1793.

Caranx hippos JORDAN and GILBERT, Proc. U. S. Nat. Mus., p. 269, 1882-JORDAN and EVERMANN, Bull. U. S. Nat. Mus., vol. 57, p. 920, 1896-BOULENGER, Bull. Mus. Zool. Anat. Torino, vol. 14, no. 346, p. 3, 1899-GILBERT and STARKS, Mem. Cal. Acad. Sci., vol. 4, p. 77, 1904-OSHIMA, Philippine Jour. Sci., vol. 26, pp. 374–375, 1925.

Material examined:

1 specimen, 254.0 mm long, at Shimonoseki fish market, Yamaguchi Prefecture, 31 October, 1950.

External:

Depth 3.15; head 3.36; from tip of snout to origin of first dorsal fin 2.73; from tip of snout to origin of second dorsal fin 1.85; from tip of snout to origin of ventral fin 3.18; from tip of snout to origin of anal fin 1.65; (numeral represents the ratio of standard length to each item). Snout 4.15; eye 5.10; interorbital space 3.80; upper jaw 2.25; height of first dorsal fin 3.31; base of the same 2.04; height of second dorsal fin 1.61; base of the same 0.88; height of anal fin 1.68; base of the same 0.98; pectoral 0.88; ventral 2.22; from anterior side of anus to origin of anal fin 2.17; length of caudal peduncle 3.31; depth of the same 2.04; ventral spine 4.44; anal spine 4.44; ratios of head length to each item. ID. VIII; IID. I, 21; A. I, 17; P. i, 20; scutes 45.

Body high, moderately compressed. Dorsal border of head strongly steep, descending from occiput to snout tip abruptly and at right angles to body axis. Head distinctly compressed, with height subequal to length. Snout short and obtuse. Maxillary reaches anterior margin of pupil; lower jaw slightly protrudes beyond the upper. Lateral line strongly arched, but straightened in the region just beneath fifth soft ray of second dorsal fin. Scutes stout, present on the straight portion of the line extending the whole length.

Color in formalin dark grayish brown above, paler below; first and second dorsals and caudal somewhat dusky, especially on their margin; other fins whitish; opercular flap with a conspicuous black spot in its upper part.

Internal:

Material consists of single specimen, with standard length 254.0 mm and cranial length 60.0 mm.

Rostral length 5.45; diameter of orbit 3.07; postorbital length 1.71; depth 1.77; width 2.31; interorbital width 3.33; ratios between cranial length and respective items.

Preorbital region of cranium very short; dorsal border from fore end of frontal to vomer steep. Mesethmoid-vomerine keel low, but well-developed. Vomer has villiform teeth arranged on a small rhomboidal area on ventral surface of its head. Superior portion of mesethmoid somewhat bulky, widened from side to side and projecting forward beyond frontals. Olfactory cavity ill-defined, replaced by a small pit; olfactory foramen present dorso-posteriorly to this pit a short distance apart. Orbital wing of ectethmoid largely expands somewhat conspicuously; anterior zygapophysis of the wing large and strongly projecting so as to be articulated to base of prepalatine process. Fronto-supraoccipital crest relatively low, with height at the center of brain case 0.26 time the depth of cranium. Supraoccipital occupying 0.7 time the median crest, and reaching in front the posterior margin of orbit. Ventral surface of parasphenoid highly keeled in the region extending from orbital floor to anterior part of prootics, but obtusely convex in the region of floor of myodome. Posterior opening of myodome small. Temporal and pterotic crests high. Pterotic window absent. Posterior spine of pterotic triangular in shape. Opisthotic with sharp process on its posterior margin. Zygapophyses of exoccipital meeting beneath foramen magnum. Supramaxillary 0.65 time as long as maxillary. Outer branch of the forked head of maxillary relatively short. Ascending process of premaxillary somewhat low, 0.41 time the length of premaxillary; articular process not surpassing ascending process, from which it is ill-defined; postmaxillary process small, somewhat round on dorsal margin. Villiform teeth on lower margin of premaxillary forming a narrow band, outer row of the teeth stronger. Dentary with a single row of canine teeth on its upper margin. Two arms of dentary makes an angle about 45°. Hyomandibular relatively long, 0.55 time as long as cranium, and with enlarged head portion; anterior two zygapophyses distinctly apart. Metapterygoid wide, quadrangular in shape, and about as long as wide. Mesopterygoid small, subtriangular in shape, 0.4 time as long as hyomandibular. Pterygoid wide and protruded at dorso-anterior corner into an elongate process. Palatine wide, and with a narrow band of villiform teeth on inner and lower margin. Glossohyal spatulate, with a similarly dentate band on dorsal surface. Urohyal narrow, and with length less than that from fore end of ceratohyal to rear end of epihyal; lateral wings conspicuously expanded. Upper member of hypohyal sharply projecting inward at its dorso-anterior corner. Ceratohyal window elongate oval in shape, located at the middle of longitudinal channel of ceratohyal. Gill-rakers on first arch $15+4=19$; the longest of them 0.74 time as long as eye diameter, and subequal to the corresponding gill-lamella. Main tubercles on the same $15+5=20$. Preorbital bone flat and wide, and 1.5 times as long as wide. Of five suborbital bones, the

fourth largest in size, 1.23 times as long as wide; the third coming next to the fourth in size. Suborbital lamina wide, in contact with first and second suborbital bones. Suborbital process longer than the lamina, compressed on a plane vertical to the lamina and razor-like in shape. Posttemporal large in size; dorsal branch much longer than the ventral. Clavicle elongate, nearly as long as cranium; external and internal shelves making a right angle. Upper member of postclavicle flat and somewhat wide; lower member of the same narrowly elongated, rib-like in appearance in the lower half. Pelvic girdle 2.4 times as long as wide. Postpelvic process long, about half as long as pelvic girdle, and forked at hind end. Interpelvic keel developed.

Remarks:

The present species which was recorded from Tainan fish market, Formosa by OSHIMA (1925), has been unknown to Japan up to the present. The distribution of the species extends from the west coast of Africa to the Atlantic coast of temperate and tropical America, and to the Indian ocean.

Caranx xanthopygus CUVIER and VALENCIENNES

Caranx xanthopygus CUVIER and VALENCIENNES, Hist. Nat. Poissons, vol. 9, p. 109, 1833-WAKIYA, Ann. Carnegie Mus., vol. 15, p. 186, pl. 24, fig. 3, 1924.

Material examined:

3 specimens, 196.0–162.0 mm long, at Kuki-ura, Mie Prefecture, November, 1956.
1 specimen, 178.0 mm long, at Tsu fish market, Mie Prefecture, 6 September, 1960.

External:

Depth 2.61–2.66; head 3.36–3.48; from tip of snout to origin of first dorsal fin 2.84–2.92; from tip of snout to origin of second dorsal fin 1.86–1.94; from tip of snout to origin of ventral fin 3.30–3.60; from tip of snout to origin of anal fin 1.69–1.83; (numeral represents the ratio of standard length to each item). Snout 3.72–3.92; eye 3.85–3.92; interorbital space 2.85–2.90; upper jaw 1.87–2.10; height of first dorsal fin 2.38–2.75; base of the same 1.76–1.83; height of second dorsal fin 1.48–1.70; base of the same 0.72–0.77; height of anal fin 1.59–1.86; base of the same 0.81–0.89; pectoral 0.97–0.86; ventral 1.94–2.16; from anterior side of anus to origin of anal fin 1.79–2.07; length of caudal peduncle 3.34–3.98; depth of the same 5.28–6.63; ventral spine 4.51–5.05; anal spine 3.79–4.80; ratios of head length to each item. ID. VIII; IID. I, 21; A. I, 17–15; P. i, 20–18; scutes 33–30.

Body high, moderately compressed. Dorsal border evenly curved from snout tip to origin of first dorsal fin. Snout somewhat obtuse, about as long as eye diameter. Maxillary reaches to posterior border of pupil; lower jaw equals to upper jaw in length. Lateral line strongly arched, but straight from the region beneath fourth soft ray of second dorsal fin backwards. Scutes present along whole length of the straight portion of the line. Caudal peduncle with 4 scutes. Breast scaly.

Color in formalin dark yellowish brown in dorsal area, gradually becoming paler downward; first dorsal fin somewhat dusky; second dorsal fin gray, but blackish in anterior falciform region; caudal fin gray, with blackish caudal margin; anal and paired fins whitish; a small black spot just above opercular flap.

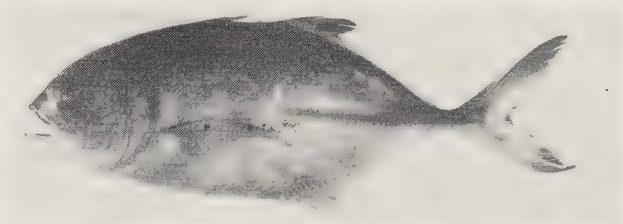

Fig. 53. *Caranx xanthopyus* Cuvier and Valenciennes, 162.0 mm in standard length.

Internal:

Material consists of a single specimen, with standard length 178.0 mm and cranial length 40.0 mm.

Rostral length 5.00; diameter of orbit 2.86; postorbital length 2.03; depth 1.57; width 2.07; interorbital width 2.90; ratios between cranial length and respective items.

Preorbital region of cranium very short; dorsal border from fore end of frontal to vomer steep. Mesethmoid-vomerine keel low but well-developed. Vomer has villiform teeth arranged in a triangular band on ventral surface of its head portion. Superior portion of mesethmoid widened from side to side and slightly projecting forward beyond frontals. Olfactory cavity scarcely developed, replaced by a small pit, from which a short distance apart dorso-posteriorly olfactory foramen is perforated. Lateral expansion of ectethmoid somewhat conspicuous and produced into moderately long anterior zygapophysis so as to be articulated to the base of prepalatine process. Fronto-supraoccipital crest somewhat low, with height at the center of brain case 0.29 time the depth of cranium. Supraoccipital occupying 0.67 time the dorsal edge of median crest, extending forward a little beyond the posterior limit of orbit. Parasphenoid on ventral surface highly keeled in the region extending from orbital floor to fore part of prootics, but obtusely round in the region of floor of myodome. Myodome with somewhat wide posterior opening. Temporal and pterotic crests high. Pterotic window absent. Pterotic bears a short, obtuse posterior spine. Zygapophyses of exoccipitals meet each other beneath foramen magnum. Supramaxillry 0.64 time as long as maxillary. Outer branch of the forked head of maxillary small in size. Ascending process of premaxillary low, 0.42 time as long as premaxillary; articular process not surpassing ascending process; the two is distinguishable from each other by a somewhat deep "V"-shaped notch; postmaxillary process small, and round on dorsal margin. Lower margin of premaxillary carries a narrow band of villiform teeth, outer series of which is composed of stronger canine teeth. Dentary has a single row of canine teeth on dorsal

margin. Angle interposed between two arms of dentary about 45°. Hyomandibular 0.52 time as long as cranium, widely expanded, quadrate in head portion, but slenderer downward; anterior two zygapophyses distinctly apart. Metapterygoid wide, nearly trapezoid in shape. Mesopterygoid relatively small, about half as long as hyomandibular. Pterygoid more or less wide at fore end, and produced at the dorso-anterior corner into a sharp process. Main portion of palatine and fore end of pterygoid flexed outwards; the flexed regions thus becoming vertical to the sagittal plane. Palatine bears a wide band of villiform teeth on inner and lower surface. Urohyal narrow, shorter than the distance from fore end of ceratohyal to hind end of epihyal, and somewhat acutely projecting at its dorso-anterior angle; lateral wings moderately expanded. Upper member of hypohyal somewhat inclined inward. Ceratohyal window reduced to slit-like aperture. Gill-lakers on first arch $17+6=23$; the longest of them 0.56 time as long as eye diameter. Main tubercles on the same $14+4=18$. Preorbital bone flat, wide, and 1.83 times as long as wide. Of five suborbital bones, the fourth the largest in size, 1.5 time as long as wide; the first and third succeeding the fourth in size. Suborbital lamina large, in contact with first and second suborbital bones. Suborbital process long, compressed on a plane vertical to the lamina and razor-like in appearance. Clavicle slightly longer than cranium; external and internal shelves making a right angle, greater part of the latter uncovered by posterior expansion of the former. Upper member of postclavicle wide and lamellar; lower member with a lamellar upper part, but with a long styliform process directed downward. Pelvic girdle 2.4 times as long as wide. Postpelvic process long, 0.37 time as long as pelvic girdle, and forked widely posteriorly. Interpelvic keel slightly developed.

Remarks:

In the digestive of the specimen 178.0 mm long, numerous fragments of shrimps and 10 fish scales (ctenoid scales) were discovered.

Although the present species was synonymized with *Caranx ignobilis* (FORSKÅL) by KAMOHARA (1958), the former is distinguishable form the latter by the possession of a small black spot above the opercular flap, and by the breast completely clothed with scales. The present author is of the opinion that *Caranx xanthopygus* CUVIER and VALENCIENNES is valid.

Caranx sexasciatus QUOY and GAIMARD

Caranx sexfasciatus QOUY and GAIMARD, Voy. Uranie, Zoologie, p. 358, pl. 65, fig. 4, 1824-BLEEKER, Nat. Geneesk. Arch. Ned. Ind., vol. 2, p. 517, 1845-JORDAN and SEALE, Bull. U. S. Bur. Fisheries, vol. 25, p. 231, 1906-SEALE and BEAN, Proc. U. S. Nat. Mus., vol. 33, p. 241, 1907-WAKIYA, Ann. Carnegie Mus., vol. 15, p. 184, pl. 25, figs. 3–4, 1924.

Caranx (Caranx) sexfasciatus WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, Vol. 6, p. 243, 1931.

Caranx forsteri CUVIER and VALENCIENNES, Hist. Poissons, vol. 9, p. 107, 1833-JORDAN and RICHARD-

SON, Mem. Carnegie Mus., vol. 4, p. 179, 1909.

Caranx flavo-caeruleus TEMMINCK and SCHLEGEL, Pisces Fauna Japonica, p. 110, pl. 59, fig. 2, 1845.

Material examined:

1 specimen, 450.0 mm long, at Yaizu, Shizuoka Prefecture, 25 March, 1958.
3 specimens, 135.0–103.0 mm long, at Owase fish market, Mie Prefecture, 7 July, 1959.
2 specimens, 89.0–60.4 mm long, at Tsu fish market, Mie Prefecture, August, 1960.

External:

Depth 2.46–3.43; head 3.18–3.63; from tip of snout to origin of first dorsal fin 2.84–3.03; from tip of origin of second dorsal fin 1.86–1.99; from tip of snout to origin of ventral fin 3.18–3.81; from tip of snout to origin of anal fin 1.75–1.81; (numeral represents the ratio of standard length to each item). Snout 3.33–4.77; diameter of eye 2.90–4.00; interorbital space 3.02–3.62; upper jaw 2.00–2.32; height of first dorsal fin 1.93–2.96; base of the same 1.94–2.16; height of second dorsal fin 1.57–1.71; base of the same 0.75–0.79; height of anal fin 1.77–2.00; base of the same 0.81–0.90; pectoral 0.81–1.14; ventral 1.80–2.22; from anterior side of anus to origin of anal fin 1.80–2.22; length of caudal peduncle 2.87–4.72; depth of the same 6.50–8.27; ventral spine 4.12–5.55; anal spine 3.88–4.80; ratios of head length to each item. ID. VIII-VII; IID. I, 22–21; A. I, 17–15; P. i, 20–19; scutes 32–30.

Body high, moderately compressed. Dorsal profile gradually descending from origin of first dorsal fin to tip of snout. Snout obtuse, slightly shorter than eye diameter. Maxillary reaches posterior limit of pupil; lower jaw equals to upper jaw in length. Lateral line strongly arched, but straight from the region beneath sixth or seventh soft ray of second dorsal fin backwards. Scutes present along whole length of the staright portion of lateral line Caudal peduncle with 4 scutes. Breast scaly.

Color in formalin dark grayish-brown in dorsal area, gradually becoming paler downward; first dorsal fin dusky; second dorsal fin more or less grayish, bordered with black on upper margin; caudal fin grayish, with blackish posterior edge; anal and paired fins whitish; a small black spot above opercular flap. In the specimen 135.0 mm long and less, body marked with seven black transverse bands, of which the first descends from the occipital across the eye.

Internal:

Material consists of a single specimen, with standard length 135.0 mm and cranial length 32.0 mm.

Rostral length 5.23; diameter of orbit 2.66; postorbital length 2.13; depth 166; width 2.06; interorbital width 3.08; ratios between cranial length and respective items.

Since the skeletal structures of the present species are largely in accord with those of *Caranx xanthopygus* CUVIER and VALENCIENNES, it may not be inappropriate

to omit a detailed description.

Remarks:

The present species which is very similar to *Caranx xanthopygus* CUVIER and VALENCIENNES in the external characters as well as in the internal ones is more or less distinctly distinguishable from the latter by the position of the beginning of the straight portion of lateral line.

Caranx melampygus CUVIER and VALENCIENNES

Caranx melampygus CUVIER and VALENCIENNES, Hist. Nat. Poissons, vol. 9, p. 116, 1833-BLEEKER, Nat. Tijds. Ned. Ind., vol. 6, p. 58, 1854-GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 446, 1860-DAY, Fishes India, p. 214, pl. 50, fig. 3, 1878-WEBER, Siboga Exped., vol. 57, Fische, p. 397, 1913-WAKIYA, Ann. Carnegie Mus., vol. 15, p. 192, 1924.

Caranx (Caranx) melampygus WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, p. 248, 1931.

Material examined:

3 specimens, 216.5–203.0 mm long, at Koniya, Amami-Ôshima, Jnne, 1958.
1 specimen, 213.0 mm long, at Izu-Ôshima, 19, Auguat, 1959.

External:

Depth 2.64–2.77; head 3.47–3.74; from tip of snout to origin of first dorsal fin 2.35–2.78; from tip of snout to origin of second dorsal fin 1.83–1.93; from tip of snout to origin of ventral fin 3.38–3.50; from tip of snout to origin of anal fin 1.75–1.80; (numeral represents the ratio of standard length to each item). Snout 3.22–3.47; eye 3.57–4.84; interorbital space 3.14–3.44; upper jaw 2.29–2.46; height of first dorsal fin 2.35–2.78; base of the same 1.83–1.93; height of second dorsal fin 1.26–1.60; base of the same 0.68–0.77; height of anal fin 1.46–1.59; base of the same 0.78–0.82; pectoral 0.82–0.88; ventral 2.15–2.40; from anterior side of anus to origin of anal fin 1.77–1.81; length of caudal peduncle 3.24–3.44; depth of the same 6.65–7.00; ventral spine 3.87–4.30; anal spine 4.61–4.84; ratios of head length to each item. ID. VIII; IID. I, 23–24; A. I, 19–20; P. i, 19–20; scutes 37–38.

Body high, much compressed. Dorsal border gradully descending from origin of first dorsal fin to snout tip. Maxillary extending beyond anterior border of eye, but not to center of pupil; lower jaw nearly equaling to upper jaw in length. Lateral line strongly arched, but straightened from the region beneath fifth or sixth soft ray of second dorsal fin. Scutes present along whole length of the straight portion of lateral line; the largest scute 0.56–0.67 time as wide as eye diameter, and found in the middle of the straight portion. Caudal peduncle with 5 scutes. Breast scaly.

Color in formalin dark bluish on dorsal area, gradually becoming paler downward; sides scattered with small black spots; first dorsal fin black; second dorsal and anal fins dusky in their anterior falcate parts; caudal fin margined with black-

ish band; paired fins whitish; no spot above opercular flap.

Internal:

Material consists of a single specimen, with standard length 216.5 mm and cranial length 49 mm.

Rostral length 3.60; diameter of orbit 3.16; postorbital length 2.21; depth 1.63; width 2.36; interorbital width 3.06; ratios between cranial length and respective items.

Mesethmoid-vomerine keel low, but well-developed. Vomerine teeth villiform, arranged on a small rhombic area on ventral surface of the bone, behind which the bone is grooved longitudinally. Superior portion of mesethmoid widening sidewise and slightly projecting beyond frontals. Olfactory cavity ill-defined, replaced by a small pit, from which a short distance apart dorso-posteriorly olfactory foramen is perforated. Ectethmoid expanded only a little. Fronto-supraoccipital crest relatively high, 0.33 time as high as the depth of cranium at the center of brain case. Supraoccipital extends 0.6 time the dorsal edge of median crest, and reaches the middle of orbit. Ventral surface of parasphenoid highly keeled in the region extending from orbital floor to anterior part of prootics, and obtusely convex in the region of floor of myodome. Myodome with a distinct posterior opening. Temporal crest relatively high, 0.35 time as fronto-supraoccipital crest at the center of parietal. Zygapophyses of exoccipitals meet together beneath foramen magnum. Supramaxillary of large size, 0.76 time as long as maxillary. Ascending process of premaxillary 0.58 time as long as premaxillary; articular process slightly shorter than ascending process, from which it is indistinctly separated; postmaxillary process low wide, and semi-circular on dorsal margin. Villiform teeth on lower margin of premaxillary in a narrow band; outer rows of the band represented by stronger ones. Dentary with a single row of canine teeth on upper margin. Urohyal shorter than distance from fore end of ceratohyal to rear end of epihyal, and with moderately expanded lateral wings. Ceratohyal window narrow, located in the middle of longitudinal groove of ceratohyal. Gill-rakers on first arch 18+8=26; the longest of them 0.66 time as long as eye diameter. Main tubercles 16+4=20. Preorbital bone flat, wide, and 1.43 times as long as wide; posterior border straight, not sinuous and in contact with first suborbital bone. Second and third suborbital bones narrow, and quadrangular in shape; fourth suborbital enlarged into a triangle, 1.47 times as long as wide. Suborbital lamina wide, closely adjoining first and second suborbital bones. Suborbital process well-developed, compressed on a plane vertical to the lamina in the form of a razor. External and internal shelves of clavicle making a right angle; the latter for the most exposed. Lower member of postclavicle more or less wide and lamellated in upper part, which is further produced into a downwardly directing rib-like process. Pelvic girdle 3.1 times as long as wide. Postpelvic process long, 0.32 time as long as pelvic girdle, and bifurcated behind. Interpelvic keel conspicuous.

Remarks:

In the digestive tube of the specimen 216.5 mm long, 2 individuals of Halcampidae, numerous fragments of shrimps and 6 fish scales (ctenoid scales) were found.

Caranx bixanthopterus RÜPPELL

Caranx bixanthopterus RÜPPELL, N. W. Fishes, p. 49, pl. 14, fig. 2, 1835-WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 190–191, pl. 27, fig. 2, 1924.

Caranx latus JENKINS (non AGASSIZ), Bull. U. S. Fish. Fish. Comm., vol. 22, p. 444, 1903.

Caranx forsteri JORDAN and EVERMANN (non CUVIER and VALENCIENNES), Bull. U. S. Fish. Comm., vol. 23, p. 191, 1905.

Material examined:

6 specimens, 180.5–155.5 mm long, at Uchiumi, Amami-Oshima, June. 1958.

External:

Depth 2.59–2.72; head 3.33–3.44; from tip of snout to origin of first dorsal fin 2.86–3.03; from tip of snout to origin of second dorsal fin 1.85–1.92; from tip of snout to origin of ventral fin 3.05–3.49; from tip of snout to origin of anal fin 1.70–1.88; (numeral represents the ratio of standard length to each item). Snout 3.14–3.55; diameter of eye 4.06–4.76; interorbital space 3.50–3.68; upper jaw 2.44–2.63; height of first dorsal fin 2.25–2.66; base of the same 1.78–2.02; height of second dorsal fin 1.46–1.49; base of the same 0.76–0.80; height of anal fin 1.49–1.72; base of the same 0.82–0.87; pectoral 0.84–0.91; ventral 2.19–2.36; length of caudal peduncle 3.38–3.88; depth of the same 6.65–6.92; from anterior side of anus to origin of anal fin 1.87–2.09; ventral spine 4.30–4.65; anal spine 4.22–4.90; ratios of head length to each item. ID. VIII-VII; IID. I, 23; A. I, 19–18; P. i, 21–19; scutes 38–34.

Contour of body resembles that of *Caranx melampygus* CUVIER and VALENCIENNES.

Color in formalin dark brownish in dorsal area, gradually becoming paler downward; second dorsal and anal fins margined by blackish band; caudal fin fringed by blackish stripe; paired fins paler in color.

Internal:

Material consists of a single specimen, with standard length 180.5 mm and cranial length 41 mm.

Rostral length 3.73; diameter of orbit 2.92; postorbital length 2.22; depth 1.64; width 2.41; interorbital width 3.15; ratios between cranial length and respective items.

The present species closely resembles *Caranx melampygus* CUVIER and VALENCIENNES in the general skeletal features except for that the shape of glossohyal is strongly different between the two species. This bone is relatively wider, being 2.5 times as long as wide, and is fringed by a narrower cartilage on the anterior margin. In

Caranx melampygus it is 3.4 times as long as wide, and bordered with a much wider cartilage.

Remarks:

This species has been regarded as a synonym of *Caranx melampygus* by OKADA and MATSUBARA (1938), MATSUBARA (1955) and KAMOHARA (1958). The present study, however, treats the two as distinct on account of the constitutional difference in the glossohyal.

Caranx ishikawai WAKIYA

Caranx ishikawai WAKIYA, Ann. Carnegie Mus., vol. 15, p. 193, pl. 26, 1924.

Material examined:

1 specimen, 377.0 mm long, at Kuki-ura, Mie Prefecture, March, 1958.

External:

Depth 2.54; head 3.66; from tip of snout to origin of first dorsal fin 3.14; from tip of snout to origin of second dorsal fin 1.87; from tip of snout to origin of ventral fin 3.77; from tip of snout to origin of anal fin 1.85; (numeral represents the ratio of standard length to each item). Snout 3.14; diameter of eye 5.05; interorbital space 3.08; upper jaw 2.52; height of first dorsal fin 3.09; base of the some 1.49; height of second dorsal fin 0.87; base of the same 0.71; height of anal fin 1.17; base of the same 0.77; pectoral 0.77; ventral 2.19; from anterior side of anus to origin of anal fin 1.84; length of caudal fin 3.22; depth of the same 6.87; ventral spine 3.80; anal spine 4.74; ratios of head length to each item). ID. VIII; IID. I, 22; A. I, 18; P. i, 20; scutes 32.

Body high, much compressed, and irregularly pentagonal in configuration. Head somewhat angularly curved in the middle of the border ranging from beginning of first dorsal fin to snout tip. Maxillary extending beyond anterior border of eye; both upper and lower jaws of some length. Breast scaly. Anterior rays of dorsal and anal fins much elongate, giving the borders a falciform appearance. Lateral line strongly arched in fore region, but straightened from third soft ray of second dorsal fin backwards. Scutes strong and large; width of the largest one 0.61 time the length of eye diameter. Caudal peduncle has 4 scutes.

Color in formalin uniformly brownish black, growing paler downward.

Internal:

Material consists of a single specimen, with standard length 3.77.0 mm and cranial length 83.0 mm.

Rostral length 3.46; diameter of orbit 3.25; postorbital length 2.24; depth 1.34; width 2.30; ratios between cranial length and respective items.

The present species which resembles *Caranx melampygus* CUVIER and VALENCIENNES in the general characteristic of the skeletal structures to some extent, is dis-

tinct from this species in some points indicated below. Superior portion of mesethmoid strongly projecting beyond frontals, deeply concave on fore margin, exhibiting a "V"-shaped appearance in dorsal view. Fronto-supraoccipital crest very high, 0.44 time as high as the depth of cranium at the center of brain case. Temporal crest relatively high, 0.38 time as high as median crest at the center of dorsal surface of parietal. Posterior opening of myodome narrow, slit-like. Lower edge of dentary with a semi-circular notch near fore end. Metapterygoid widely expanded, its greatest width equaling to about a half the length of hyomandibular; anterior free margin nearly straight. Gill-rakers on first arch 20+6=26; longest of them 0.56 time as long as eye diameter, and subequal to the corresponding gill-lamella in length. Main tubercles on the same 17+5=22.

Remarks:

The foregoing statement is in agreement with the original description of WAKIYA (1924) except for the presence of some trifle discrepancies. Ratio between standard length and depth of body is 2.54 in the present specimen unlike 2.3 in the original description, and the number of scutes is 32 instead of 30.

Genus *Atropus* CUVIER

Body high, strongly compressed. Abdomen with a deep longitudinal groove, in which ventral fin can be folded. Scutes feebly spinulated, present on the straight portion of lateral line. Preorbital region of cranium very short. Olfactory cavity undeveloped. Superior portion of mesethmoid not projecting beyond frontals. Fronto-supraoccipital crest strongly elevated. Myodome with a distinct posterior opening. Zygapophyses of exoccipitals for articulation to atlas meet each other beneath foramen magnum. Ventral surface of parasphenoid highly keeled in its anterior half. Ascending process of premaxillary short, and somewhat discriminable from articular process by a very shallow notch; postmaxillary process small in size, and obtusely pointed. Hyomandibular as well as metapterygoid relatively narrow. Mesopterygoid large in size, 0.6 time as long as hyomandibular. Pterygoid not particularly enlarged anteriorly, though with a sharp dorsal process. Urohyal expanded slightly and horizontally. Preorbital bone flat and narrow. Suborbital lamina nearly ovate, and in contact with first and second suborbital bones. Suborbital process rod-shaped. Clavicle long; external and internal shelves meet in a right angle. Lower part of hypocoracoid relatively broad and with somewhat triangular appearance. Postpelvic process vertical to pelvic girdle. Interpelvic keel well-developed. Last three pairs of parapophyses combined by bony bridge. Inferior vertebral foramina well developed in last three parapophyses and first haemal spine.

Remarks:

Despite the close resemblance to *Caranx* and *Citula*, the genus is fundamentally

different from these in having the abdomen deeply grooved on the ventral side, in which the ventral fins are folded.

Atropus atropus (BLOCH and SCHNEIDER)

Brama atropus BLOCH and SCHNEIDER, p. 98, pl. 23, 1801.
Caranx nigripes CUVIER and VALENCIENNES, vol. 9, p. 122, 1833.
Caranx atropus GÜNTER, Cat. Fishes British Mus., vol. 2, p. 450, 1860.
Atropus atropus WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 211–212, pl. 32, figs. 1–3, 1924.

Material examined:

2 specimens, 179.5–178.0 mm long, at Persian Gulf, March, 1957.
2 specimens, 251.0–214.0 mm long, at Formosa, January, 1960.
1 specimen, 178.0 mm long, at Kuki-ura, Mie Prefecture, March, 1960.

External:

Depth 1.95–2.06; head 3.66–4.06; from tip of snout to origin of first dorsal fin 2.92–3.30; from tip of snout to origin of second dorsal fin 2.04–2.18; from tip of snout to ventral fin 3.80–3.88; from tip of snout to origin of anal fin 1.80–2.02; (numeral represents the ratio of standard length to each item). Snout 3.68–3.88; diameter of eye 3.12–3.34; interorbital space 2.55–2.76; upper jaw 2.15–2.21; height of first dorsal fin 2.63–2.94; base of the same 1.88–2.26; height of second dorsal fin 1.85–1.99; base of the same 0.53–0.56; height of anal fin 1.85–2.04; base of the same 0.57–0.68; pectoral 0.64–0.78; ventral 0.82–1.01; from anterior side of anus to origin of anal fin 1.35–1.51; length of caudal peduncle 2.94–3.29; depth of the same 4.48–4.85; ventral spine 2.82–3.23; anal spine 5.40–6.22; ratios of standard length to each item. ID. VII; IID. I, 22; A. I, 18–17; P. i, 18–17; scutes 35–34.

Body high, much compressed. Dorsal margin of head strongly curved in occipital region. Maxillary reaching the middle of pupil; lower jaw longer than the upper. Dorsal border of head and nape as well as ventral border of isthmus and breast highly keeled. Breast naked as far back as pectoral on dorsal side and as ventrals on ventral side. Lateral line strongly arched in front, straightened backward from fourth or fifth softh ray of second dorsal fin. Feebly spinnulated scutes present on the straight portion of lateral line; largest of them 0.49 time as wide as eye diameter. Caudal peduncle with 5 scutes.

Color in formalin brownish black in dorsal area, gradually paler downward; first dorsal fin brownish black; second dorsal fin whitish, fringed by black margin; pectoral and anal fins whitish; ventral fin blackish except for outer and basal white areas; caudal fin gray terminating in blackish margin.

Internal:

Material consists of a single specimen, with standard length 178.0 mm and cranial length 40.5 mm.

Rostral length 5.06; diameter of orbit 2.31; postorbital length 2.53; depth 1.23;

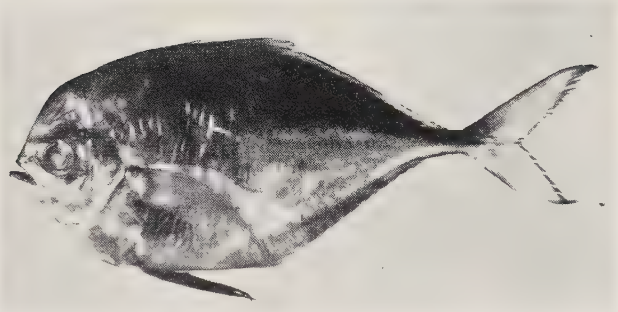

Fig. 54. *Atropus atropus* (BLOCH and SCHNEIDER), 251.0 mm in standard length.

width 2.02; ratios between cranial length and respective items.

Preorbital region of cranium extraordinarily shortened. Mesethmoid-vomerine keel more or less elevated. Vomer with villiform teeth crowdedly arranged in a rhomboidal band on ventral face of head portion which is round. Superior portion of mesethmoid not extending beyond frontals. Olfactory cavity obliterated. Fronto-supraoccipital crest high, 0.45 time as high as cranium at its center. Ventral surface of parasphenoid highly keeled in the region of orbital floor, but evenly convex in the region of floor of myodome. Posterior opening of myodome large, sub-quadrate in ventral aspect. Pterotic window small in size. Pterotic with short but sharp posterior spine. Zygapophyses of exoccipitals for the articulation to atlas narrowly meet each other beneath foramen magnum. Supramaxillary 0.61 time as long as maxillary. Ascending process of maxillary short, 0.37 time as long as maxillary; articular process not surpassing ascending process, the two indistinctly distinguishable owing to very shallow notch; postmaxillary process much reduced in length, and more or less round on upper margin. Dorsal arm of dentary rather narrow; its narrowest region 0.44 time as wide as that of ventral arm. Narrow band crowded with villiform teeth present on lower margin of premaxillary and on upper margin of dentary. Hyomandibular narrow and elongate, 0.68 time as long as cranium; anterior two zygapophyses united with each other. Mesopterygoid 0.6 time as long as hyomandibular, and extending from posterior part of dorsal border of palatine to the middle of anterior free margin of metapterygoid. Pterygoid not widened anteriorly, but produced into a sharp process at dorso-anterior corner. Palatine subtriangular in lateral view, and with villiform teeth on lower and inner surface. Opercle relatively narrow, 2.3 times as wide as long, and slightly convex on anterior margin. Interopercle shorter than opercle. Glossohyal proportionally short, spatulate, and without tooth on dorsal surface. Urohyal triangular, shorter than the distance extending from fore end to rear end of epihyal, yet longer than ceratohyal, and a little horizontally expanded. Ceratohyal window obovate, located at the middle of longitudinal groove of ceratohyal. Gill-rakers on first arch $21+9=30$; the longest of them reaching the half of eye diameter in length. Main tubercles $14+4=18$, circular or irregularly polygonal in shape and carrying a prominent,

thickly spinulated wart in the middle of anterior border. Preorbital bone narrow and flat, and twice as long as wide; posterior border entire and straight. Second and third suborbital bones very narrow, rod-shaped, fourth suborbital somewhat wider. Suborbital lamina 1.7 times as long as wide, nearly ovate, and in contact with first and second suborbital bones. Suborbital process rod-like, 0.71 time as long as suborbital lamina. Clavicle elongated downward, 1.36 times as long as cranium; external and internal shelves at a right angle. Hypocoracoid 0.67 time as long as clavicle, subtriangular. Lower member of postclavicle widened and lamellated in its upper quarter, though elongated into a long rib-like process in its lower three quarters. Pelvic girdle narrow, compressed, 4.15 times as long as wide. Postpelvic process stout, 0.3 time as long as pelvic girdle, projecting vertically above pelvic girdle, and not forked at dorso-posterior angle. Interpelvic keel well-developed.

Remarks:

More or less mature ovary was detected from the specimen 178.0 mm long collected at Kuki-ura. In the digestive tube of the same specimen two individuals of Halocynthia and sandy muds were found.

Genus *Citula* CUVIER

Body high, strongly compressed, naked on breast. Scutes present on the straight portion of lateral line. Preorbital region of cranium relatively short and wide. Fronto-supraoccipital crest high. Myodome opens posteriorly. Zygapophyses of exoccipitals meet each other beneath foramen magnum. Parasphenoid highly keeled on ventral surface in its anterior half. Ascending process of premaxillary relatively long; articular process not surpassed by ascending process, from which it is distinguished by a deep notch. Mesopterygoid large in size. Pterygoid wide anteriorly, but sharply produced into a dorso-anterior process. Lateral wings of urohyal only slightly expanded. Preorbital bone flat and wide. Suborbital lamina large, in contact with first and second suborbital bones. Suborbital process long, rod-like. Pelvic girdle more or less narrowed. Interpelvic keel well-developed. Last four pairs of parapophyses connected by bony bridges. Inferior vertebral foramina present in last four parapophyses and first haemal spine.

Remarks:

Although *Citula* is most nearly allied to *Caranx* in general characterisics, the former is distinguished from the latter in having the naked breast, the rod-like suborbital process and the large mesopterygoid.

Key to species

1a Outer branch of the forked head of maxillary wider than that of posterior re-

gion; upper margin of ceratohyal highly raised in its anterior portion; hypercoracoid shorter than a quarter of hypocoracoid; hypocoracoid relatively wide in its lower part and not abruptly narrowed.

2a Lower member of postclavicle rod-like; posttemporal about as high as long; interhyal shorter than glossohyal…………***Citula malabaricus***

2b Lower member of postclavicle widened and lamellar for some length in its upper part, but bearing a long rod-like process; posttemporal 0.6 time as high as long; interhyal subequal to glossohyal in length…………***Citula plumbeus***

1b Outer branch of the forked head of maxillary subequal to that of posterior region; upper margin of ceratohyal almost straight; hypercoracoid longer than a quarter of hypocoracoid; hypocoracoid elongated into a slender rod at its ventro-anterior end…………***Citula dinema***

Citula armatus (FORSKÅL)

Sciaena armatus FORSKÅL, Descript. Animal, p. 53, 1775.

Citula armatus CUVIER and VALENCIENNES, Hist. Nat. Poissons, vol. 9, p. 127, 1833-GÜNTHER, Cat. Eishes British Mus., vol. 2, p. 453, 1860-JORDAN and SEALE, Bull. U. S. Bur. Fisheries, vol. 26, p. 14, 1790-JORDAN and RICHARDSON, Bull. U. S. Bur. Fisheries, vol. 27, p. 250, 1908.

Caranx (Citula) armatus WAKIYA, Ann. Carnegie Mus., vol. 15, p. 169, pl. 20, fig. 1, 1924.

Caranx (Citula) schlegeli WAKIYA, Ann. Carnegie Mus., vol. 15, p. 170, pl. 20, fig. 2, 1924.

Carangoides armatus FOWLER, Proc. Acad. Nat. Sci. Phila., vol. 79, p. 272, 1927-FOWLER Mem. Bishop Mus., vol. 10, p. 151, 1928.

Caranx (Carangoides) armatus WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, p. 233, 1931.

Material examined:

1 specimen, 116.5 mm long, at Shimonoseki fish market, Yamaguchi Prefecture, 31 October, 1950.

External:

Depth 1.95; head 3.46; from tip of snout to origin of first dorsal fin 3.05; from tip of snout to origin of second dorsal fin 1.94; from tip of snout to origin of ventral fin 3.05; from tip of snout to origin of anal fin 1.73; (numeral represents the ratio of standard length to each item). Snout 3.19; diameter of eye 3.35; interorbital space 2,68; upper jaw 2.31; height of first dorsal fin 2.12; base of the same 2.39; height of second dorsal fin 0.68; base of the same 0.64; height of anal fin 0.98; base of the same 0.74; pectoral 0.89; ventral 1.66; from anterior side of anus to origin of anal fin 1.76; length of caudal peduncle 4.19; depth of the same 5.99; ventral spine 3.53; anal spine 4.47; ratios of head length to each item. ID. VIII; IID. I, 21; A. I, 17; P. i, 19; scutes 19.

Body nearly ovate, strongly compressed. Dorsal border of head curving rapidly from occipital downward to snout tip. Snout more or less obtuse, only slightly longer than eye diameter. Maxillary extending beyond anterior margin of pupil. Posterior nostril subequal to the anterior in size. Lateral line moderately arched

in anterior region, straight from fourteenth soft ray of second dorsal fin backward. Breast naked on a broad area. First soft ray of second dorsal fin elongates into a long filament, only slightly shorter than fin base. First soft ray of anal fin filamentous, 0.75 time as long as fin base. Scutes small in size, present in posterior two thirds of the straight portion of lateral line. Caudal peduncle has 8 scutes.

Color in formalin brownish above, light below; first dorsal fin dusky; second dorsal and anal fins nearly grayish, though with black ends; pectoral fin pale gray; ventral dusky for some measure.

Internal:

As only a single material was available, osteology of the species was unable to study.

Citula plumbeus Quoy and Gaimard

Citula plumbea Quoy and Gaimard, Voy. Uramie Zool., p. 361, 1824.
Caranx plumbeus Jordan and Seale, Bull. U. S. Bur. Fisheries, vol. 25, p. 233, fig. 28, 1906.
Caranx (*Citula*) *plumbeus* Wakiya, Ann. Carnegie Mus., vol. 15, pp. 172–173, pl. 20, fig. 3, 1924.

Material examined:

2 specimens, 216.0–201.0 mm long, at Persian Gulf, March, 1957, collected by Dr. Reizo Ishiyama, Professor of Shimonoseki College of Fisheries.

1 specimen, 200.5 mm long, at Kuki-ura, Mie Prefecture, 2 April, 1960.

External:

Depth 1.68–2.02; head 3.46–3.64; from tip of snout to origin of first dorsal fin 2.75–3.04; from tip of snout to origin of second dorsal fin 1.91–2.00; from tip of snout to origin of ventral fin 3.43–3.46; from tip of snout to origin of anal fin 1.75–1.83; (numeral represents the ratio of standard length to each item). Snout 3.49–3.70; diameter of eye 3.12–3.56; interorbital space 2.58–2.72; upper jaw 2.12–2.13; height of first dorsal fin 2.06–2.46; base of the same 2.04–2.13; height of second dorsal fin 0.43–0.48; base of the same 0.62–0.63; height of anal fin 0.57; base of the same 0.72–0.74; pectoral 0.71–0.78; ventral 1.81–1.91; from anterior side of anus to origin of anal fin 1.66–2.06; length of caudal peduncle 3.41–3.43; depth of the same 5.27–5.40; ventral spine 1.81–1.91; anal spine 4.92–5.50; ratios of head length to each item. ID. VIII; IID. I, 21; A. I, 17; P. i, 18; scutes 25–21.

Body tall, ovate, much compressed. Dorsal border evenly arched, but abruptly descending from occipital forward. Maxillary extending to the middle of pupil; lower jaw subequal to upper jaw in length. Posterior nostril larger anterior nostril in vertical as well as transverse calibers, being 1.6 times as large as latter. Breast naked as far upward as pectoral, and a little back beyond ventrals. Lateral line moderately arched in fore region, straightened from thirteenth soft ray of second dorsal fin backward. Scutes relatively small, with feeble armature, and found on posterior two-thirds of the straight portion of lateral line. Caudal peduncle with 8

scutes. First and sixth to eleventh soft rays filamentous both in second and in anal fins.

Color in formalin dark grayish brown dorsally, gradually growing paler ventrally; first dorsal fin whitish, its anterior margin washed with blackish brown; second dorsal fin grayish, margined by brownish narrow stripe; anal fin with numerous small dusky spots in membraneous part; paired fins whitish.

Internal:

Material consists of a single specimen, with standard length 201.0 mm and cranial length 49.0 mm.

Rostral length 4.26; diameter of orbit 2.30; postorbital length 2.54; depth 1.26; width 1.94; ratios between cranial length and respective items.

Mesethmoid-vomerine keel distinct but low. Vomer has a rhomboidal band crowded with villiform teeth on ventral surface of its head portion, and moderately deep longitudinal groove. Olfactory cavity ill-defined, and replaced by a small pit; olfactory foramen is found a short distance apart from this pit dorso-posteriorly. Fronto-supraoccipital crest very high, 0.46 time as high as cranium at the center of brain case. Supraoccipital 0.63 time as long as the dorsal edge of median crest, reaching to the middle of orbit forward. Ventral surface of parasphenoid highly keeled in the region of orbital floor, and obtusely convex in the region of floor of myodome. Pterotic window obsolete. Posterior spine of pterotic stout and short. Zygapophyses of exoccipitals meet beneath foramen magnum. Posterior opening of myodome wide and subquadrate in ventral aspect. Supramaxillary 0.55 time as long as maxillary. Outer branch of the forked head of maxillary wider than posterior region of the same. Ascending process of maxillary 0.56 time as long as premaxillary; articular process not surpassing ascending process, the two distinct owing to a deep notch; postmaxillary process relatively large in size and with obtuse upper margin. Lower margin of premaxillary and upper margin of dentary bear each a narrow band crowded with villiform teeth. Hyomandibular slender, 0.63 time as long as cranium; anterior two zygapophyses closely adjoining each other. Mesopterygoid relatively large-sized, about a half as long as hyomandidular, and reaching the middle of anterior margin of metapterygoid. Pterygoid enlarged at fore end and with an elongate dorso-anterior process. Palatine wide, nearly rhomboidal in lateral aspect, and crowded on a wide band with villiform teeth on its inner and lower surfaces. Opercle triangular in shape, 1.90 times as long as wide. Interopercle shorter than opercle. Glossohyal spatulate in from, with villiform teeth thickly arranged in a narrow band on dorsal surface. Urohyal more or less triangular, 1.5 times as long as wide, longer than ceratohyal, but not exceeding the distance from fore end of ceratohyal to rear end of epihyal, and having lateral wings only slightly expanded. Upper margin of ceratohyal undulated with anterior portion strongly raised. Ceratohyal window oblong ovate, located at the middle of longitudinal ceratohyal groove. Gill-rakers on first arch 15+8=23;

longest of them 0.46 time the eye diameter and slightly shorter than the corresponding gill-lamella. Main tubercles $15+4=19$; each of them little bulged; prickles covering the anterior side stouter than those on other side. Preorbital bone wide and flat, 1.42 times as long as wide. Suborbital bones small, rod-like in form. Suborbital lamina ovate, 1.23 times as long as wide. Clavicle elongate, 1.3 times as long as cranium. Hypercoracoid very small and irregularly quadrangular in shape. Hypocoracoid 0.63 time as long as clavicle, and somewhat widened and flattened in its lower part. Lower member of postclavicle rod-like except for short upper region which is lamellated and triangular. Pelvic girdle narrowly compressed, and 4.6 times as long as wide. Postpelvic process thick and short, 0.22 time as long as pelvic girdle, and with slightly forked dorso-posterior end. Interpelvic keel well-developed.

Remarks:

In the digestive tube of the specimen with standard length 200.5 mm three individuals of Halcampidae, numerous fragments of shrimps and fish muscles were found.

This species shows a close resemblance to *Citula armatus* (Forskal), but differs in that the posterior nostril has a larger caliber than the anterior one.

Jordan and Seale (1906) reported the male of the present species as having a number of rays of the second and anal fins produced into long filaments in their middle regions. With respect to this point, all the male specimens examined in the present study are in accord with the statement of those authors.

Citula malabaricus (BLOCH and SCHNEIDER)

Scomber malabaricus Bloch and Schneider, Syst. Ichth., p. 31, 1801.

Caranx malabaricus Cuvier and Valenciennes, Hist. Nat. Poissons, vol. 9, p. 121, 1833-Canter, Asiatic Soc. Bengal, vol. 18, p. 1110, 1850-Günther, Cat. Fishes British Mus., vol. 2, p. 436, 1860-Weber, Siboga-Exped., vol. 57, Fische, p. 394, 1913-Fowler and Bean, Proc. U. S. Nat. Mus., vol. 62, p. 20, 1922-Barnard, Ann. South African Mus., p. 541, 1925.

Carangoides malabaricus Fowler, Proc. Acad. Nat. Sci. Phila., vol. 57, p. 83, 1905-Oshima, Philippine Jour. Sci., vol. 26, p. 390, 1925-Fowler, Proc. Acad. Nat. Sci. Phila., vol. 79 p. 272, 1927.

Caranx (*Citula*) malabaricus Wakiya, Ann. Carnegie Mus., vol. 15, p. 178, pl. 23, fig. 3, 1924.

Caranx (*Carangoides*) *malabaricus* Weber and de Beaufort, Fishes Indo-Australian Archipelago, vol. 6, p. 237, fig. 47, 1931.

Material examined:

2 specimens, 196,0–171.0 mm long, at Owase fish market, Mie Prefecture, 31, October, 1951.

External:

Depth 2.20–2.22; head 3.42–3.11; from tip of snout to origin of first dorsal fin 2.63–2.99; from tip of snout to origin of second dorsal fin 1.80–1.96; from tip of snout to origin of ventral fin 2.95–2.97; from tip of snout to origin of anal fin 1.71–

1.78; (numeral represents the ratio of standard length to each item). Snout 3.09–3.14; eye 3.24; interorbital space 3.24–3.44; upper jaw 2.25–2.29; base of first dorsal fin 1.78–2.08; base of second dorsal fin 0.70–0.78; base of anal fin 1.80–1.96; pectoral 0.84–0.92; ventral 2.25–2.50; from anterior side of anus to origin of anal fin 1.94–2.04; length of caudal fin 3.96–4.47; depth of the same 7.00–7.05; ventral spine 4.56–5.35; anal spine 5.47–5.54; ratios of head length to each item. ID. VIII; IID. I, 23–22; A. I, 19–18; P. i, 19; scutes 25.

Body high, much compressed. Dorsal border of head steeply inclined, describing a curvature from origin of first dorsal fin to snout tip. Snout obtuse, short, but slightly longer than diameter of eye. Maxillary extending to anterior margin of eye; lower jaw slightly longer than upper jaw. Lateral line strongly curved in front, but straight behind fourteenth ray of second dorsal fin. Scutes small in size, feebly ridged on surface, and distinct in posterior four fifths of the straight portion of lateral line.

Color in formalin brownish; fins uniformly white, though edged with faint blackish stripes in second and caudal fins.

Fig. 55. *Citula malabaricus* (Bloch and Schneider), 162.0 mm in standard length.

Internal:

Material consists of a single specimen, with standard length 196.0 mm and cranial length 51.0 mm.

Rostral length 3.19; diameter of orbit 2.25; postorbital length 2.84; depth 1.50; width 2.17; interorbital width 3.29; ratios between cranial length and respective items.

Cranium high, somewhat compressed. Preorbital region of cranium relatively long. Meseethmoid-vomerine keel moderately well-developed. Vomer has a large rhomboidal band crowded with villiform teeth on ventral surface of its head portion, and is highly keeled in the region of median shaft. Superior portion of mesethmoid not projecting forward beyond frontals. Olfactory cavity obsolete, strongly swollen instead of being depressed. Fronto-supraoccipital crest highly elevated, 0.27 time as high as cranium. Supraoccipital occupying 0.6 time the dorsal edge

of median crest, and extending to the middle of orbit. Ventral surface of parasphenoid highly keeled in the region of orbital floor, but remaining to show an obtuse convexity in the region of floor of myodome. Posterior opening of myodome very narrow. Pterotic window obliterated. Posterior spine of pterotic short and thick. Sphenotic expanded laterally, though small in size. Basisphenoid with a sharp lower end, and apart from dorsal margin of parasphenoid. Zygapophysee of exoccipitals meeting each other beneath foramen magnum. Supramaxillary 0.6 time as long as maxillary. Maxillary has outer branch of its fork much wider than posterior region of the same. Ascending process of premaxillary 0.73 time as long as premaxillary, surpassing articular process; the two processes distinct from each other by a somewhat deep notch. Villiform teeth forming a narrow band on lower margin of premaxillary and on upper margin of dentary. Hyomandibular very narrow, 0.57 time as long as cranium; anterior two zygapophyses distinctly apart. Metapterygoid wider anteriorly than posteriorly, and without metapterygoid lamina on inner face. Mesopterygoid relatively large in size, and a little more than a half of hyomandibular in length. Pterygoid wider anteriorly and with an elongate dorso-anterior process. Palatine wide, nearly quadrangular in lateral aspect, and with a narrow band of villiform teeth on its inner and lower surfaces; prepalatine process slender and elongate. Opercle twice as long as wide and slightly longer than interopercle. glossohyal small in size, with villiform teeth on its dorsal surface. Urohyal almost triangular, shorter than distance from fore end of ceratohyal to rear end of epihyal, somewhat sharp at its dorso-anterior angle, and very narrow lateral wings. Upper face of ceratohyal highly raised in its anterior portion. Gill-rakers on first arch 26+10=36; the longest of them 0.45 time the eye diameter, and subequal to the corresponding gill-lamella. Main tubercles 18+4=22; each of them moderately raised, and with thick coat of tiny prickles; these are somewhat stouter on the anterior side. Preorbital bone flat, almost quadrangular in form, and 1.18 times as long as wide. First suborbital bone wide, 0.23 time as long as wide; the rest slender and rod-like in form. Suborbital lamina in contact with first and second suborbital bones, and widely expanding inward. Suborbital process long, rod-shaped. Posttemporal bone stout, and with very thick ventral branch. Clavicle 1.1 times as long as cranium; external and internal shelves making a right angle. Hypocoracoid long, and widened particularly in its lower part. Lower member of postclavicle rod-like without forming any expansion. Pelvic girdle narrow, 4.5 times as long as wide. Postpelvic process short and slightly forked at its posterior end. Interpelvic keel well-developed.

Remarks:

In the digestive tube of the specimen with standard length 196.0 mm one individual of Ascidiacea and six fish scales (ctenoid scales) were found.

Citula dinema (BLEEKER)

Carangoides dinema BLEEKER, Nat. Tijds. Ned. Ind., vol. 1, p. 365, 1851.

Caranx dinema GÜNTHER, Cat. Fritish Mus., vol. 2, p. 425, 1860-HERRE, Copeia, no. 3, p. 148, 1945.

Caranx (Citula) dinema WAKIYA, Ann. Carnegie Mus., vol., 15, p. 178, pl. 23, fig. 2, 1924.

Caranx (Carangoides) dinema WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, p. 241, 1931.

Material examined:

1 specimen, 220.0 mm long, at Owase fish market, Mie Prefecture, 13, November, 1956.

1 specimen, No. 187646 (Collection of Department of Fisheries, Faculty of Agriculture, Kyoto University) 193.0 mm long, at Yôrô, Kyoto Prefecture, June, 1955.

External:

Depth 2.20–2.22; head 3.32–3.77; from tip of snout to origin of first dorsal fin 2.97-3.29; from tip of snout to origin of second dorsal fin 1.91–2.06; from tip of snout to origin of ventral fin 3.33–3.39; from tip of snout to origin of anal fin 1.71–1.75; (numeral represents the ratio of standard length to each item). Snout 3.58–3.89; eye 3.84–4.17; interorbital space 2.90–3.07; upper jaw 2.34–2.40; height of first dorsal fin 2.10–2.15; base of the same 2.18–2.24; height of second dorsal fin 0.55, base of the same 0.61–0.64; height of anal fin 0.54; base of the same 0.61–0.67; pectoral 0.73–0.78; ventral 1.73–1.90; from anterior side of anus to origin of anal fin 1.52–1.89; length of caudal peduncle 3.70–3.89; depth of the same 4.86–4.89; ventral spine 3.49–3.76; anal spine 3.30–3.58; ratios of head length to each item. ID. VIII; IID. I, 18; A. I, 17; P. i, 19–20; scutes 27.

Body oblong, much compressed. Nape not much elevated. Dorsal border even, describing gentle curve from origin of first dorsal fin to tip of snout. Maxillary reaching center of orbit; two jaws equal in length. Lateral line moderately arched, but straight from eleventh or twelfth soft ray of second dorsal fin backward. Scutes 27 in number, relatively large, spinulated and present along entire length of the straight portion of lateral line; width of the largest one 0.46–0.57 time the eye diameter. Breast naked. First soft rays of second and anal fins produced into very long filaments.

Color in formalin almost uniformly brownish; fins gray; second dorsal fin with brownish black margin; opercle spotted by a relatively distinct, brown patch.

Internal:

Material consists of a single specimen, with standard length 220.0 mm and cranial length 47.0 mm.

Rostral length 3.62; diameter of orbit 2.85; postorbital length 2.47; depth 1.67; width 2.09; interorbital width 3.03; ratios between cranial length and respective items.

Mesethmoid-vomerine keel moderately elevated. Vomer thickly dentate in a rhomboidal ventral area on its head portion, and obtusely convex in its body on the

same face. Superior portion of mesethmoid only slightly protruding beyond frontals. Olfactory cavity wide but rather shallow. Fronto-supraoccipital crest high, 0.4 time as high as cranium. Supraoccipital occupying 0.7 time the dorsal edge of median crest, reaching the middle of orbit. Ventral surface of parasphenoid highly keeled in the region of orbital floor, and somewhat obtusely convex in the region of floor of myodome. Myodome has narrow posterior aperture. Pterotic window small, nearly circular in shape. Posterior spine of pterotic blunt and short. Zygapophyses of exoccipitals meeting each other beneath foramen magnum. Supramaxillary well-developed, 0.62 time as long as maxillary. Ascending process of premaxillary 0.71 time as long as this bone and surpassed by articular process; the two processes clearly discriminated by a deep notch; postmaxillary process moderately long, directed dorso-posteriorly. Villiform teeth forming a narrow band on lower margin of premaxillary as well as on upper margin of dentary. Anterior two zygapophyses of hyomandibular widely apart from each other. Mesopterygoid relatively large in size, 0.61 time as long as hyomandibular. Pterygoid wider anteriorly and somewhat sharply projecting dorso-anteriorly; inner and lower surfaces armed with villiform teeth forming a short band, which is a continuation of palatine dentation. Interopercle proportionally small in size, and shorter than opercle. Glossohyal spatulate, and with villiform teeth arranged in an oblong oval band on dorsal surface. Urohyal with a slight lateral expansion, and shorter than distance from fore end of ceratohyal to rear end of epihyal, yet longer than ceratohyal. Gill-rakers on first arch $19+9=28$; the longest of them 0.59 time the eye diameter. Main tubercles on the same $13+4=17$; each of them moderately bulged and with thick coat of small prickles, which are somewhat stouter on anterior side. Preorbital bone relatively wide, 1.28 times as long as wide, almost straight, and entire on posterior border. First suborbital bone triangular; second and third quadrangular, Suborbital lamina broad, 1.2 times as long as wide, and in contact with first and second suborbital bones. Suborbital process short, rod-shaped. External and internal shelves of clavicle intersecting at a right angle. Upper member of postclavicle lamellar, more or less reniform; lower member of the same somewhat broad and lamellar in upper part, but rib-like appearance in lower half. Pelvic girdle relatively wide, and 3 times as long as wide. Postpelvic process well-developed, 0.24 time as long as pelvic girdle, and widely forked posteriorly. Interpelvic keel moderate in development.

Genus *Alectis* RAFINESQUE

Body very strongly compressed, subrhomboidal in from. First dorsal fin composed of free, rudimentary spines. Anterior rays of second dorsal and anal fins produced into very long filaments. Scutes present only on the straight portion of lateral line, small in size. Cranium narrow, and somewhat compressed. Preorbital region of cranium more or less elongated. Olfactory cavity shallow but distinct.

Orbital wing of ectethmoid round in outline and insensibly continuing upward to frontal without forming an angle. Fronto-supraoccipital crest very highly elevated. Myodome with wide posterior aperture. Zygapophyses of exoccipitals in close contact with each other beneath foramen magnum. Ventral surface of parasphenoid highly keeled in the region of orbital floor. Outer branch of maxillary fork wide. Ascending process of premaxillary long, and more or less distinct from articular process by a "V"-like notch. Dentary and articular broad. Pterygoid widened anteriorly, and produced into sharp dorsn-anterior process. Urohyal very wide, with ill-defined lateral wings. Preorbital wide and flat. Suborbital lamina moderate in development. Suborbital process absent. Clavicle and hypocoracoid narrown and elongate. Lower member of postclavicle rod-shaped. Pelvic girdle narrow and compressed. Interpelvic keel well-developed. Last three pairs of parapophyses combined together by bony bridges. Inferior vertebral foramina present in last three parapophyses and first haemal spine.

Key to species

1a Rostral part a quarter as long as cranium; orbital diameter smaller than postorbital length; pterotic window present; ascending process of premaxillary shorter than premaxillary; urohyal provided in anterior part of ventral border with a spiniform process; supraclavicle moderately elongated, a quarter as wide as long............***Alectis ciliaris***

1b Rostral part a half as long as cranium; orbital diameter larger than postorbital length; pterotic window absent; ascending process of premaxillary longer than premaxillary; urohyal without a spiniform process in anterior part of ventral border; supraclavicle much slender and elongated, one sixth as wide as long............***Alectis major***

Alectis ciliaris (BLOCH)

Zeus ciliaris BLOCH, Natueges. Ausland, Fische, vol. 6, p. 29, pl. 191, 1787.

Caranx ciliaris GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 454, 1860-GÜNTHER, Fische der Südsee, vol. 2, p. 135, pl. 69, 1876–1881.

Carangus ciliaris SEALE, Occas. Papers Bishop Mus., vol. 1, p. 17, 1902.

Alectis ciliaris JORDAN and EVERMANN, Bull. U. S. Fish. Comm., vol. 23, part 1, p. 200, fig. 78, 1905-WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 213–214, pl. 32, fig. 4, 1924-WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, p. 269, 1931.

Blepharis indicus CUVIER and VALENCIENNES, vol. 9, p. 154, 1833.

Alectis indicus WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 214–215, 1924.

Alectis temmincki WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 215–216.

Alectis breviventralis WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 216–217, pl. 33, fig. 1.

Material examined:

5 specimens, 239.0-114.0 mm long, at Owase fish market, Mie Prefecture, 5 August, 1957.

External:

Depth 1.20–1.58; head 3.12–1.58; from tip of snout to origin of first dorsal fin 2.57–2.79; from tip of snout to origin of second dorsal fin 1.94–2.08; from tip of snout to origin of ventral fin 3.95–4.16; from tip of snout to origin of anal fin 1.81–1.86; (numeral represents the ratio of standard length to each item). Snout 3.08–4.35; eye 2.67–3.45; interorbital space 2.66–3.08; upper jaw 2.43–2.57; base of first dorsal fin 2.56–2.88; base of second dorsal fin 0.61–0.62; base of anal fin 0.65–0.69; pectoral 0.81–0.97; ventral 1.60–1.77; from anterior side of anus to origin of anal fin 1.60–1.84; length of caudal peduncle 3.68–4.35; depth of the same 6.00–7.50; ventral spine 2.16–2.40; anal spine 12.8–15.2; ratios of head length to each item. ID. VI; IID. I, 19–18; A. I, 16; P. i, 18–17; scutes 13–11.

Body extraordinarily compressed, subrhomboidal in shape. Dorsal border linear, descending gradually from origin of second dorsal fin to occiput, from which it runs almost vertically to snout tip through an angle. Snout short and obtuse; maxillary reaching frontal border of pupil; lower jaw slightly longer than upper jaw. Lateral line strongly arched, but straight from tenth or eleventh soft ray of second dorsal fin caudally. Scutes small in size, feeble, distinct only on posterior half of the straight portion of lateral line; largest one 0.15–0.20 time the eye diameter in width. First seven rays of second dorsal fin and first five of anal fin exceedingly elongate, first of both the rays especially long, attaining the length of body.

Color in formalin dark grayish brown in dorsal area, growing paler downward, and striped by six dusky subvertical bands on the sides; a large black blotch on second dorsal fin, covering from first to seventh soft rays; another blotch with a diffuse outline on anal fin, extending from first to fifth soft rays; ventral fin blackish from first to fourth rays in distal part, whitish in other region; opercle spotted with blackish pattern.

Fig. 56. *Alectis ciliaris* (Bloch), 114.5 mm in standard length.

Internal:

Material consists of a single specimen, with standard length 239.0 mm and cranial length 54.2 mm.

Rostral length 4.02; diameter of orbit 2.50; postorbital length 2.64; depth 1.34; width 1.94; interorbital width 2.64; ratios between cranial length and respective items.

Mesethmoid-vomerine keel low and obtuse. Vomer with four conical teeth in its head on ventral surface, and with a shallow longitudinal groove on the midline. Superior portion of mesethmoid thick, and slightly projecting beyond frontals. Olfactory cavity wide but shallow. Fronto-supraoccipital crest highly elevated, 0.37 time as high as cranium. Temporal and pterotic crests well-developed. Pterotic window a small pore. Ventral surface of parasphenoid highly keeled in the region of orbital floor, but obtusely convex in the region of floor of myodome. Posterior opening of myodome wide. Posterior spine of pterotic thick and stout. Zygapophyses of exoccipitals meet each other beneath foramen magnum. Supramaxillary 0.6 time the length of maxillary. Outer branch of the forked portion of maxillary very wide, and 1.7 times as wide as posterior region. Ascending process of premaxillary 0.68 time the entire length of the bone; articular process slightly shorter than ascending process, the two interposing a "V"-shaped notch; postmaxillary process relatively large in size and linguiform. Lower margin of premaxillary and upper margin of dentary bear conical teeth, forming a narrow band. Dentary widely expanding, and occupying two thirds the ventral border of lower jaw; ventral arm more than wider twice dorsal arm. Hyomandibular narrowly elongate, 0.7 time as long as cranium; anterior two zygapophyses close to each other. Mesopterygoid flat and somewhat large, 0.54 time as long as hyomandibular. Pterygoid wider anteriorly, and sharply projecting at its dorso-anterior corner. Palatine wide, subquadrangular in lateral aspect, and armed with a band of villiform teeth on its inner and lower surfaces. Opercle relatively wide, 1.7 times as long as wide. Interopercle shorter than opercle. Glossohyal small in size, flattened, spatulate, and furnished with villiform teeth on dorsal surface. Urohyal wide, provided with somewhat blunt dorso-anterior projection, clavate dorso-posterior process, slightly expanded into lateral wings on anterior half of ventral border and ending in medio-ventral spiniform process. Length of urohyal slightly smaller than distance from fore end of ceratohyal to rear end of epihyal. Ceratohyal window relatively small, elongate oval in shape, and located at the middle of longitudinal groove. Gill-rakers on first arch $15+5=20$; the longest of them 0.38 time the eye diameter. Main tubercles on the same $25+4=29$; each of these tubercles nearly disc-shaped, and thickly clothed with prickles. Preorbital bone wide, flat, pentagonal, and only slightly longer than wide. Suborbital lamina well-developed, and in contact with second and third suborbital bones. Suborbital process absent. Posttemporal thick and stout. Supraclavicle relatively long, and smooth on outer surface. Clavicle slenderly elongated, with 1.6 times as long as cranium; external and internal shelves

making a right angle. Hypercoracoid very small, nearly triangular in shape, and slightly shorter than one fifths the hypocoracoid. Upper membr of postclavicle wide and lamellar, but lower member rod-shaped. Pelvic girdle narrow, compressed, and 3.7 times as long as wide. Postpelvic process sharp but somewhat short, and with forked end. Interpelvic keel well-developed.

Remarks:

In the digestive tube of the specimen 205.0 mm long two cuttle fishes and several fish vertebrae were found.

After his careful examination, NAKAMURA (1936) expressed his view that *Alectis indicus* (CUVIER and VALENCIENNES), *A. temmincki* WAKIYA and *A. breviventralis* WAKIYA, all of which were considered by WAKIYA (1924) as valid, may represent nothing but growth stages of *A. ciliaris* (BLOCH). The author is in complete agreement with NAKAMURA in rendering those as synonyms of this species.

Alectis major (CUVIER and VALENCIENNES)

Gallichthys major CUVIER and VALENCIENNES, vol. 9, p. 168, pl. 254, 1833.

Caranx gallus GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 455, 1860.

Alectis ciliaris JORDAN and EVERMANN, (non BLOCH), Proc. U. S. Nat. Mus., vol. 14, p. 338, 1903-SENO, Report on Fishery Industry of Formosa, p. 119, 1910.

Alectis major JORDAN and RICHARDSON, Mem. Carnegie Mus., vol. 4, p. 180, 1909-WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 217-218, pl. 34, fig. 1, 1924.

Material examined:

1 specimen, 154.0 mm long, at Shimonoseki fish market, Yamaguchi Prefecture, 31 October, 1950.

External:

Depth 1.46; head 3.04; from tip of snout to origin of first dorsal fin 2.96; from tip of snout to origin of second dorsal fin 2.26; from tip of snout to origin of ventral fin 4.40; from tip of snout to origin of anal fin 2.23; (numeral represents the ratio of standard length to each item). Snout 3.60; eye 3.36; interorbital space 3.74; upper jaw 2.63; base of first dorsal fin 1.99; base of second dorsal fin 0.59; base of anal fin 0.71; pectoral 0.75; ventral 1.05; from anterior side of anus to origin of anal fin 1.74; length of caudal peduncle 3.68; depth of the same 7.22; ventral spine 2.97; anal spine 8.42; ratios of head length to each item. ID. V; IID. I, 19; A. I, 16; P. i, 16; scutes 8.

Body deep, nearly pentagonal, and strongly compressed. Dorsal border from fore end of second dorsal fin to occiput linear and gradually descending but rapidly towards the snout, through an angle. Snout obtuse, about as long as eye diameter; maxillary hardly reaching fore border of eye; two jaws equal in length. Lateral line strongly arched, but straight from tenth soft ray of second dorsal fin backward. Scutes small in number, feebly developed, distinct only on posterior half of the staight portion of lateral line.

Color in formalin uniformly light grayish brown.

Internal:

Material consists of a single specimen, with standard length 154.0 mm and cranial length 49.5 mm.

Rostral length 2.36; diameter of orbit 2.86; postorbital length 3.61; depth 1.51; width 2.68; interorbital width 3.72; ratios between cranial length and respective items.

Cranium high, strongly compressed. Preorbital region much elongated. Mesethmoid-vomerine keel somewhat distinct in the region of vomer, but indistinct in the region of mesethmoid. Superior portion of mesethmoid ridged, projecting beyond frontals, and forming fore region of fronto-supraoccipital crest. Ventral surface of vomer has a narrow band crowded with villiform teeth on its head. Olfactory cavity well-developed. Orbital wing of ectethmoid round in outline and continuing gracefully upward to frontal without forming an angle. Fronto-supraoccipital crest 0.46 time as high as cranium. Supraoccipital occupying 0.72 time the dorsal edge of median crest, reaching the middle of orbit. Parasphenoid scarcely curved upward at the region beneath basisphenoid; ventral surface sharply keeled in the region of orbital floor. Posterior opening of myodome relatively wide. Basisphenoid very narrow and delicate. Temporal and pterotic crests low. Pterotic window absent. Posterior spine of pterotic short but sharp. Zygapophyses of exoccipitals meeting each other beneath foramen magnum. Supramaxillary 0.62 time as long as maxillary. Outer branch of the maxillary fork wide and ovate. Ascending process of premaxillary very long, 1.3 times as long as the bone; articular process slightly shorter than that, from which it is distinguishable by a deep notch; postmaxillary process relatively long, but not pointed. Dentary wide, with greatest width 0.87 time the length of dentary, and occupying the greater part of the ventral border of lower jaw. Villiform teeth form a narrow band on lower margin of premaxillary as well as on upper margin of dentary. Hyomandibular narrow, elongated, 0.62 time as long as cranium; anterior two zygapophyses distinctly apart. Mesopterygoid lamellar, and somewhat small in size. Quadrate taking an equilateral triangle in profile, and without a process at its dorso-posterior corner. Pterygoid wider anteriorly and produced at its dorso-anterior angle into a sharp process. Palatine wide, quadrangular in lateral aspect, and with a narrow band of villiform teeth on its inner and lower surfaces. Glossohyal rod-like in shape; dorsal surface thickly beset with villiform teeth. Urohyal widely expanding, bluntly produced at its dorso-anterior corner, and with slight lateral expansion; its length smaller than distance from fore end of ceratohyal to rear end of epihyal, but longer than the ceratohyal. Ceratohyal window elongate oval in shape, situated at the middle of longitudinal groove of ceratohyal. Gill-rakers on first arch short but stout, $23+9=32$ in number; the longest of them 0.3 time the diameter of eye. Main tubercles on the same $22+6=28$; each of them quadrangular or circular in shape, and thick-

ly covered with prickles. Preorbital bone very wide, flat, and 0.5 time as long as wide. Suborbital bones 6 in number; first suborbital largest, triangular in shape, whereas second suborbital smallest, scale-like in shape; others narrowed, and rod-shaped. Suborbital lamina wide, and in contact with first and second suborbital bones. Suborbital process ill-defined. Supraclavicle very long, 1.24 times as long as cranium; external and internal shelves making a right angle. Hypercoracoid subquadrangular, and much reduced in size. Upper number of postclavicle relatively wide, lower member of the same rod-shaped. Pelvic girdle strongly compressed, and 4.8 times as long as wide. Postpelvic process short, disc-like, 0.15 time as long as pelvic girdle, and standing on a level vertical to the main part of girdle. Interpelvic keel well-developed.

Remarks:

Although the present species seems to be widely distributed throughout the Indian ocean and the tropical seas of Pacific, it has not as yet been known to Japan.

Genus *Gnathanodon* BLEEKER

Body high, moderately compressed. Scutes present only on posterior half of the straight portion of lateral line. Preorbital region of cranium somewhat long. Mesethmoid-vomerine keel plate-like, and highly elevated. Olfactory cavity wide and deep. Fronto-supraoccipital crest widely expanding. Superior portion of mesethmoid retreating from fore ends of frontals, under which it forms a deep depression. Pterotic window wide. Myodome with wide perforation on posterior side. Zygapophyses of exoccipitals meeting each other beneath foramen magnum. Ventral surface of parasphenoid keeled in the region of orbital floor, and with a posterior bulge containing a conical cavity opening backward under prootics. Supramaxillary and maxillary expanding. Ascending process of premaxillary elongate and indistinctly distinguishable from articular process. Metapterygoid lamina well-developed. Mesopterygoid much reduced in size, and flattened on dorsal surface. Pterygoid wider anteriorly, with dorso-anterior corner pointed but not produced. Jaws, vomer, palatine and glossohyal not dentate. Suborbital lamina large, ovate, and in contact with first and second suborbital bones. Suborbital process ill-defined. External shelf of clavicle slightly wider than internal shelf. Interpelvic keel moderate in development. Parapophysis devoid of bony bridge. Inferior vertebral foramina developed in last three parapophyses and first haemal spine.

Remarks:

The genus closely resembles *Selaroides* in that the mesethmoid-vomerine keel is highly elevated like a disc, in that the outer branch of the maxillary fork is widely expanding, in that the ascending process of premaxillary is elongate, in that the pterotic window is very wide, and finally in that the metapterygoid lamina is well-developed. The former is distinguishable from the latter by that the olfactory

cavity is wide, by that the ventral surface of parasphenoid is keeled in the region of orbital floor and has a well-developed protuberance in the region lying under prootics, by that the suborbital lamina is wide in spite of the ill development of the suborbital process, and by that parapophyses lack the bony bridge.

Gnathanodon speciosus (FORSKÅL)

Scomber rim speciosus FORSKÅL, Descript. Animal, p. 54, 1775.

Caranx speciosus LACÉPÈDE, Hist. Nat. Poissons, vol. 3, p, 72, pl. 1, fig. 1, 1802-GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 444, 1860-JORDAN and SEALE, Bull. U. S. Bur. Fish., vol. 26, p. 14, 1907-EVERMANN and SEALE, Bull, U. S. Bur. Fish. vol. 26, p. 64, 1907.

Gnathanodon speciosus BLEEKER, Nat. Tijds. Ned. Ind., vol. 1, p. 160, 1851-OSHIMA, Philippine Jour. Sci., vol. 26, p. 403, 1925-HERRE, Fishery Resources Philippine Islands, pp. 29 and 55, pl, 21, 1927-FOWLER, Proc. Acad. Nat. Sci. Phila., vol. 79, p. 271, 1927-FOWLER, Mem. Bishop Mus., vol. 10, p. 149, 1928.

Caranx (Gnathanodon) speciosus WAKIYA, Ann. Carnegie Mus., vol. 15, p. 209, pl. 31, fig. 3, 1924-WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, p. 264, fig. 50, 1931.

Material examined:

2 specimens, Nos. 2806-2807 (Collection of Department of Zoology, Faculty of Science, Tokyo University), 196.0–202.0 mm long, at Palau Islands, 21 October, 1936, collected by Dr. Tokiharu ABE.

External:

Depth 2.30–2.36; head 2.99–3.31; from tip of snout to origin of first dorsal fin 2.85–3.12; from tip of snout to origin of second dorsal fin 1.92–2.40; from tip of snout to origin of ventral fin 2.97–3.44; from tip of snout to origin of anal fin 1.76–1.90; (numeral represents the ratio of standard length to each item). Snout 2.70–3.07; eye 4.56–5.05; interorbital space 3.20–3.29; upper jaw 2.47–2.60; height of first dorsal fin 2.82–3.07; base of the same 2.16–2.25; height of second dorsal fin 2.04–2.08; base of the same 0.72–0.81; height of anal fin 1.99–2.09; base of the same 0.82–0.93; pectoral 0.92–0.96; ventral 2.13–2.14; from anterior side of anus to origin of anal fin 2.04–2.29; length of caudal peduncle 3.76–4.50; depth of the same 4.94–5.72; ventral spine 4.32–4.82; anal spine 4.74–4.93; ratios of head length to each item. ID. VII; IID. I, 19–20; A. I, 17; P. i, 22; scutes 18–19.

Body deep, strongly compressed. Dorsal border strongly convex. Snout blunt, and longer than diameter of eye. Maxillary reaching or only slightly exceeding fore border of eye; lower jaw slightly longer than upper jaw. Lateral line moderately arched, straight from eighth soft ray of second dorsal fin backwards. Scutes small in number, feebly spinulose, and present only on posterior half of the straight portion of lateral line.

Color in formalin uniformly grayish brown; nine or ten dusky cross band on the side, the first band passing eye obliquely.

Internal:

Material consists of a single specimen, with standard length 202.0 mm and cranial length 50.0 mm.

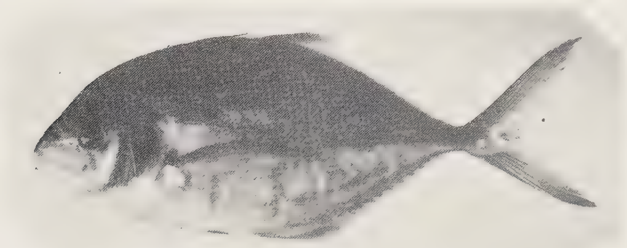

Fig. 57. *Gnathanodon speciosus* (Forskål), 202.0 mm in standard length.

Rostral length 2.94; diameter of orbit 3.33; postorbital length 2.63; depth 1.41; width 2.08; interorbital width 2.86; ratios between cranial length and respective items.

Vomer toothless. Mesethmoid-vomerine keel highly elevated, and plate-like in the region of vomer. Superior portion of mesethmoid forms a large, deep depression beneath diverging fore ends of frontals. Olfactory cavity wide, deep, and circular in outline. Fronto-supraoccipital crest broad. Supraoccipital reaches the middle of orbit on the dorsal edge of median crest. Pterotic window large in size, and nearly ovate. Ventral surface of parasphenoid with a sharp edge in the region of orbital floor, and a large protuberance enclosing a conical cavity with a posterior opening in the region lying under prootics. Zygapophysis of exoccipital joins that of the opposite side beneath foramen magnum. Posterior opening of myodome wide and large. Supramaxillary wide, subquadrate in form, and about thrice as long as wide. Maxillary thick and stout, undulated on ventral edge; outer branch of the forked end broad, and wider than the posterior region of the bone. Ascending process of premaxillary distinctly longer than premaxillary; postmaxillary process narrow and somewhat sharply pointed. Upper process of articular much elongated, with length attaining to about half that of articular. Premaxillary and dentary edentulous. Hyomandibular relatively narrow; anterior two zygapophyses consoliated together. Metapterygoid lamina well-developed. Mesopterygoid very small, shorter than half the length of hyomandibular, and nearly flattened on upper surface. Pterygoid wider anteriorly than posteriorly and sharply pointed at dorsal angle. Prepalatine process thick, large, and indistinguishable from the main part of palatine. Palatine toothless. Glossohyal spatulate, and toothless on dorsal surface. Urohyal with lateral wings moderately expanded, shorter than distance from fore end of ceratohyal to caudal end of epihyal, yet longer than ceratohyal. Ceratohyal window oblong ovate, placed about the middle of longitudinal groove of ceratohyal. Interhyal particularly large-size, about as long as glossohyal. Gill-rakers on first arch $22+6=28$ in number. Main tubercles on the same $19+4=23$; each of them discoidal in form, and thickly covered by prickles subepual in size. Preorbital bone flattened, enlarged, almost linear on posterior border, and 1.23 times as long as wide. Suborbital lamina wide, nearly oval in shape, and 1.42 times as long as

wide. Suborbital process ill-defined. Supraclavicle somewhat slender and elongate. External shelf of clavicle extending backward to cover the greater part of internal shelf; two shelves maklng approximately a right angle. Pelvic girdle relatively narrow, 3.1 times as long as wide. Postpelvic process 0.4 time as long as pelvic girdle, and forked at posterior end. Interpelvic keel present.

Remarks:

OSHIMA (1925), in his description of this species, stated of the teeth as being very small, granular, and lost with age. It is natural that premaxillary, dentary, vomer and palatine are all toothless in the present adult.

Genus *Selaroides* BLEEKER

Body moderately compressed, oblong in shape. Scutes present only on the straight portion of lateral line, small in size, and feebly spinulose. Preorbital region of cranium somewhat elongated. Mesethmoid-vomerine keel highly elevated, assuming an appearance of a thin plate in the region of vomer, but obliterated in the region of mesethmoid. Olfactory cavity very narrow and deep. Fronto-supraoccipital crest wide. Pterotic window large-sized. Myodome with a posterior foramen. Zygapophyses of exoccipitals meeting each other beneath foramen magnum. Outer branch of maxillary fork thick and broad. Ascending process of premaxillary very long. Rostral cartilage strongly compressed, triangular in lateral aspect. Metapterygoid lamina well-developed. Pterygoid wider anteriorly; its dorso-anterior corner pointed but not produced into a process. Urohyal without dorso-anterior process; lateral wings expanding. Preorbital bone not very wide, but bulged outward on outer surface. Suborbital lamina small in size, and in contact with first suborbital bone. Suborbital process elongated into aciform. Pelvic girdle somewhat narrow. Interpelvic keel absent. Last three pairs of parapophyses connected together by bony bridges. Inferior vertebral foramina present in last three parapophyses and first haemal spine.

Selaroides leptolepis (CUVIER and VALENCIENNES)

Caranx leptolepis CUVIER and VALENCIENNES, Hist. Poissons, vol. 9, p. 63, 1833.

Caranx leptolepis BLEEKER, Nat. Geneesk. Arch. Ned. Ind., vol. 2, p. 517, 1845-GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 440, 1860-DAY, Fishes India, p. 225, pl. 51, fig. 4, 1878-JORDAN and RICHARDSON, Bull. U. S. Bur. Fisheries, vol. 27, p. 250, 1908-FOWLER, Copeia, no, 58, p. 63, 1918-McCulloch, Mem. Australian Mus., vol. 5, p. 188, 1929.

Selaroides leptolepis BLEEKER, Nat. Tijds. Ned. Ind., vol. 2, p. 213, 1851.

Leptapis leptolepis BLEEKER, Verh. Bat., Gen., vol. 24, pp. 71 and 87, 1852.

Caranx (*Selaroides*) *leptolepis* WAKIYA, Ann. Carnegie Mus., vol. 15, p. 208, pl. 31, fig. 2, 1924-WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, p. 262, fig. 49, 1931.

Gnathanodon leptolepis FOWLER, Proc. Acad. Nat. Sci. Phila., vol. 79, p. 271, 1927.

Material examined:

1 specimen, 124.0 mm long, at Kumano-nada, September, 1953.

2 specimens, Nos. 27394–27395 (Collection of Department of Fisheries, Faculty of Agriculture, Kyoto University), 120.0–128.0 mm long, at Tonkin Bay, June, 1957.

External:

Depth 2.84–2.98; head 3.20–3.52; from tip of snout to origin of first dorsal fin 2.78–2.94; from tip of snout to origin of second dorsal fin 1.85–1.94; from tip of snout to origin of ventral fin 3.20–3.43; from tip of snout to origin of anal fin 1.75–1.87; (numeral represents the ratio of standard length to each item). Snout 3.09–3.35; eye 3.40–3.68; interorbital space 3.03–3.43; upper jaw 2.42–2.58; height of first dorsal fin 2.22; base of the same 2.12–2.18; height of second dorsal fin 2.14–2.36; base of the same 0.69–0.74; height of anal fin 2.40–2.74; base of the same 0.69–0.80; pectoral 0.88–0.93; ventral 2.00–2.36; from anterior side of anus to origin of anal fin 1.72–1.83; length of caudal peduncle 3.66–4.10; depth of the same 5.96–6.42; ventral spine 4.26; anal spine 3.65–4.12; ratios of head length to each item. ID. VIII; IID. I, 24–25; A. I, 21; P. i, 18–19; scutes 30–33.

Body low, moderately compressed. Snout somewhat pointed. Maxillary reaching frontal border of eye; lower jaw slightly longer than upper jaw. Anterior adipose eyelid inconspicuous; posterior eyelid broad, extending to posterior border of pupil. Lateral line scarcely curved, straight from tenth soft ray of second dorsal fin backwards. Scutes small in size, feebly armed, present on entire length of the straight portion of lateral line. Caudal peduncle with 8 scutes.

Color in formalin brownish; fins paler; opercle spotted with black.

Internal:

Material consists of a single specimen, with standard length 124.0 mm and cranial length 30.0 mm.

Rostral length 4.00; diameter of orbit 2.31; postorbital length 2.77; depth 1.88; width 1.93; interorbital width 2.72; ratios between cranial length and respective items.

Vomer toothless. Mesethmoid-vomerine keel highly raised like a thin plate in the region of vomer, but obliterated and replaced by a deep concavity. Olfactory cavity very narrow but deep, and furnished with olfactory foramen on its posterior side. Fronto-supraoccipital crest wide. Supraoccipital on the dorsal edge of median crest reaches fore border of eye. Wing-like portion of sphenotic more or less evenly round. Pterotic window very wide. Ventral surface of parasphenoid somewhat narrow and flattened in the region of orbital floor. Zygapophyses of exoccipitals meeting each other. Posterior opening of myodome relatively wide. Outer branch of maxillary fork thick and wide; its greatest width subequal to that of maxillary. Premaxillary toothless; ascending process highly elevated, and as long as the bone; postmaxillary process somewhat sharply projecting; rostral cartilage triangler in lateral aspect, and strongly compressed. Dentary with a single series of teeth on

its upper margin. Anterior two zygapophyses of hyomandibular conjoin each other at the ends. Metapterygoid lamina well-developed. Mesopterygoid slightly shorter than hyomandibular. Pterygoid wider in its anterior part and with pointed dorso-anterior corner. Palatine edentulous. Opercle about as long as interopercle. Glossohyal spatulate, and toothless on dorsal surface. Urohyal without dorso-anterior process, but with lateral expansions on ventral border; its length smaller than distance from anteriormost of ceratohyal to posteriormost of epihyal, and yet longer than ceratohyal. Ceratohyal window elongate ovoidal in shape, and located at the middle of longitudinal groove of ceratohyal. Interhyal falling between entire length and the half of glossohyal. Gill-rakers on first arch slender, elongated, 27+11=38 in number. Main tubercles 19+7=26; each of them with a ridge, and thickly clothed with prickles, all subequal in size. Preorbital bone 1.5 times as long as wide, and bulged outward on outer surface. Suborbital lamina small, aliform, and in contact with first suborbital bone. Suborbital process slender, elongated into aciform. Supraclavicle with disc-like expansion at about the middle of its anterior side. External and internal shelves making a right angle; the latter for the most part exposed from posterior expansion of the former; anterior shelf somewhat distinctly expanded. Pelvic girdle relatively narrow, and 3.8 times as long as wide. Postpelvic process with length equal to width of girdle, and forked at posterior end. Interpelvic keel obsolete.

Remarks:

KAMOHARA (1958) synonymized *Longirostrum mertensi* (CUVIER and VALENCIENNES) and *L. delicatissimus* (DÖDERLEIN) with the present species on account of their close resemblance in external characters. So for as *L. delicatissimus* concerns, it is entirely different from the present species in the mesethmoid-vomerine keel highly raised into a thin plate in the region of vomer, in the very narrow and deep olfactory cavity, in the wide pterotic window, in the zygapophyses of exoccipitals joining each other, in the thick and wide outer branch of maxillary fork, in the strongly compressed triangular rostral cartilage, in the well-developed metapterygoid lamina, and in the urohyal deprived of dorso-anterior process. For these reasons the author can not advocate KAMOHARA's view.

Genus *Uraspis* BLEEKER

Body deep, somewhat compressed. Scutes spinulose, present along entire length of the straight portion of lateral line; scute disc-like produced in front into a spine. Skeleton rather fragile in its structure. Preorbital region of cranium exceedingly short. Olfactory cavity absent. Superior portion of mesethmoid retreating from fore ends of frontals, beneath which it forms a deep concavity. Zygapophyses of exoccipitals meeting each other beneath foramen magnum. Asecending process of premaxillary long, and distinct from articular process by a deep "V"-shaped notch;

postmaxillary process relatively small in size. Pterygoid somewhat wide in anterior part, and without dorso-anterior process. Prepalatine process bulky in its upper part. Lateral wings of urohyal only slightly expanded. Preorbital bone flat, nearly quadrate. Suborbital lamina large, and in contact with first and second suborbital bones. External and internal shelves of clavicle meeting at a right angle. Hypercoracoid small in size. Interpelvic keel well-developed. Bony bridge absent from any pair of parapophysis. Inferior vertebral foramina small in size and present in last three parapophyses and first haemal spine. Second to fourth haemal spines with disc-like enlargement on their anterior sides.

Remarks:

The present genus is sharply distinguishable from other Japanese member of this family by having scute which is strongly armed and provided with a median keel enlarged in front into a disc ending in a stout spine, by having the skeleton fragile in its structure, by the possession of prepalatine process bulky in its upper part, and by the anterior three haemal spines having disc-like enlargement on their anterior margins.

Uraspis helvolus (FORSTER)

Scomber helvolus FORSTER, Descr. Anim., p. 315, 1844.

Caranx helvolus CUVIER and VALENCIENNES, Hist. Nat. Poissons, vol. 9, p. 104, 1833-BLEEKER, Nat. Tijd. Ned. Ind., vol. 8, p. 419, 1855-GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 443, 1860-JORDAN and SEALE, Bull. U. S. Bur. Fisheries, vol. 26, p. 232, 1906.

Caranx (Uraspis) helvolus WAKIYA, Ann. Carnegie Mus., vol. 15, p. 206, pl. 28, fig. 4.

Caranx (Uraspis) micropterus WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 206–207, pl. 30, fig. 2.

Apes helvolus OSHIMA, Philippine Jour. Sci., vol. 26, pp. 385–386, 1925.

Material examined:

5 specimens, 242.0–202.0 mm long, at Owase fish market, Mie Prefecture, 21 September, 1951.
3 specimens, 280.0–259.0 mm long, at Kuki-ura, Mie Prefecture, 8–9 November, 1957.

External:

Depth 2.18–2.38; head 3.41–3.75; from tip of snout to origin of first dorsal fin 3.17–3.50; from tip of snout to origin of second dorsal fin 2.34–2.47; from tip of snout to ventral fin 3.76–4.12; from tip of snout to origin of anal fin 1.77–1.87; (numeral represents the ratio of standard length to each item). Snout 3.34–3.98; eye 4.03–4.82; interorbital space 2.44–2.52; upper jaw 2.05–2.48; height of first dorsal fin 3.48–3.90; base of the same 2.81–2.90; height of second dorsal fin 1.59–1.73; base of the same 0.54–0.61; height of anal fin 1.52–1.62; base of the same 0.59–0.79; pectoral 0.88–1.01; ventral 1.03–1.67; from anterior side of anus to origin of anal fin 1.61–1.96; length of caudal peduncle 4.06–4.86; depth of the same 4.87–5.25; ventral spine 2.73-3.49; anal spine 5.29–5.86; ratios of head length to each item. ID. VIII; IID. I, 30–28; A. I, 22; P. i, 24–22; scutes 37–34.

Body somewhat deep, moderately compressed. Snout obtuse, longer than caliber of eye. Maxillary reaching beyond fore border of eye, or at times even beyond fore border of pupil. Adipose eyelid rudimentary. Lateral line moderately curved, becoming straight from twelfth or thirteenth soft ray of second dorsal fin backwards. Scutes present along entire length of the straight portion of lateral line; largest of them 0.33–0.44 time the diameter of eye; they are ridged on the surface ending in front in a spine. Breast naked for the greater part of its area. Second and anal fins not falcate.

Color in formalin almost uniformly dark brownish.

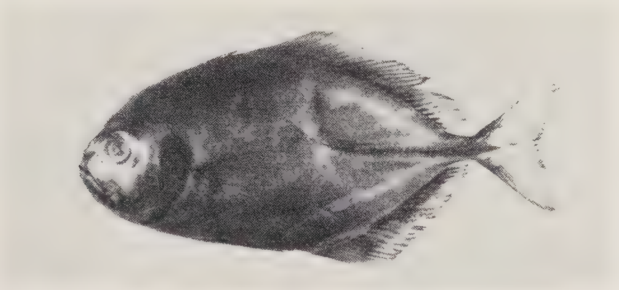

Fig. 58. *Uraspis helvolus* (FORSTER), 204.0 mm in standard length.

Internal:

Material consists of two specimens, with standard length 280.0–204.0 mm and cranial length 64.5–47.3 mm.

Rostral length 4.39–4.50; diameter of orbit 2.33–2.36; postorbital length 2.36–2.52; depth 1.30–1.33; width 1.82–1.85; interorbital width 2.22–2.36; ratios between cranial length and respective items.

Preorbital region of cranium short, and obtuse at fore end. Vomer toothless on ventral surface at its head, and bluntly convex along midline of its shaft. Superior portion of mesethmoid enlarged beneath diverging fore ends of frontals to forming an anteriorly opening concavity. Olfactory cavity undeveloped. Ectethmoid somewhat large and thickened, but inconspicuous in its lateral expansion. Fronto-supraoccipital crest a half as high as cranium. Supraoccipital occupying 0.65 time the dorsal edge of median crest, and extending to fore border of orbit. Sphenotic small in size, and scarcely extending laterally. Ventral surface of parasphenoid narrow and flat in the region of orbital floor. Myodome without a foramen at posterior end. Pterotic window present. Posterior spine of pterotic short but sharp. Two neural pores on the side of exoccipital more strongly reduced in size than in other carangid species. Zygapophyses of exoccipitals meeting each other beneath foramen magnum. Supramaxillary about half as long as maxillary. Ascending process of premaxillary occupying 0.55 time the length of the bone, and distinct from articular process by a deep "V"-shaped notch; postmaxillary process relatively small in size, and round in dorsal margin. Lower margin of premaxillary and up-

per margin of dentary with conical teeth arranged in a single series. Hyomandibular somewhat narrow, elongated, with 0.55 time as long as cranium; anterior two zygapophyses in contact with each other. Metapterygoid lamina obliterated. Mesopterygoid 0.7 time as long as hyomandibular. Pterygoid somewhat wider anteriorly, and without dorso-anterior process. Palatine toothless, but with two antero-posteriorly arranged facets on its upper and inner surfaces; prepalatine process bulky in its upper portion. Urohyal more or less expanding, with a triangular dorso-anterior process, and gracefully arched on posterior margin; lateral wings only slightly expanding. Ceratohyal window elongate ovoidal, and located in the middle of longitudinal groove of ceratohyal. Interhyal narrow and elonger than glossohyal. Gill-rakers on first arch $14-13+5=18-19$; the longest of them 0.47 time the diameter of eye, and of about equal length to the corresponding gill-lamella. Main tubercles on the same $11+3=14$; they are strongly protruding, wart-like in appearance, and scarcely covered with prickles except at their tops, which are crowded with stouter ones. Preorbital bone flat, subquadrangular in form, almost straight in its posterior border, and 1.6 times as long as wide. First suborbital bone quadrangular in form and coming next to preorbital bone in size. Second and third suborbitals small, rod-shaped. Fourth suborbital somewhat elongated, and a little wider in the middle region. Suborbital lamina 1.3 times as long as wide, and in contact with first and second suborbital bones. Suborbital process obsolete. Post-temporal forked into thick, stout, widely diverging branches. Clavicle 1.18 times as long as cranium; external and internal shelves at a right angle. Upper member of postclavicle wide, and flattened, but lower member much narrower and elongated. Pelvic girdle somewhat narrow, and 3.86 times as long as wide. Postpelvic process sharp at tip, and widely forked in its posterior half. Interpelvic keel well-developed.

Remarks:

In addition of this species, *Uraspis micropterus* RÜPPELL and *U. uraspis* GÜNTHER were recorded from the genus *Uraspis* in the neighboring seas of Japan by WAKIYA (1924). *Uraspis micropterus* may be regarded as a synonym of the present species, since the differences in the depth of body, relative position of the posterior end of maxillary, length of gill-raker, and ventral length can not be enough to separate them as distinct species. *U. uraspis*, on the other hand, appears to be a valid species because of the arrangement of teeth in two series on jaws and of the presence of six cross bands on the body side.

Genus *Carangoides* BLEEKER

Body somewhat deep, compressed. Breast non-scaly. Scutes relatively small, and present on the straight portion of lateral line extending entire length. Preorbital region of cranium wide but not very short. Olfactory cavity well-developed.

Superior portion of mesethmoid retreating from diverging fore ends of frontals, beneath which it is widened and forms a large sinus. Fronto-supraoccipital crest high. Posterior perforation of myodome so narrow as to refuse the insertion of a needle. Zygapophyses of exoccipitals meeting each other. Ventral surface of parasphenoid highly keeled in the region of orbital floor. Ascending process of premaxillary relatively long, and slightly surpassing articular process. Lateral wings of urohyal only slightly expanded. Preorbital bone wide and flat. Suborbital lamina large, and in contact with first and second suborbital bones. Suborbital process short. External shelf of clavicle slightly wider than internal shelf, the two making a right angle. Pelvic girdle narrow, with interpelvic keel. Last three pairs of parapophyses combined by bony bridges. Inferior vertebral foramina well-developed in last three parapophyses and first haemal spine.

Key to species

1a Cranial length 3.58 times the rostral length; postpelvic process thick and short ....***Carangoides jordani***

1b Cranial length 3.94 times the rostral length; postpelvic process somewhat slender and elongated............***Carangoides hemigymnostethus***

Carangoides jordani NICHOLS

Carangoides jordani NICHOLS, Amer. Mus. Nov., no. 50, p. 2, 1922.
Carangoides ferdau jordani WOODS, U. S. Nat. Mus. Bull., 202, pp. 518–519, pl. 46, B, 1953.

Material examined:

2 specimens, Nos. 19346–19347 (Collection of Department of Fisheries, Faculty of Agriculture, Kyoto University), 241.0–245.0 mm long, at Yôrô, Kyoto Prefecture, June, 1955, collected by Dr. MATSUBARA, Professor of Kyoto University.

External:

Depth 2.47–2.50; head 3.49–3.55; from tip of snout to origin of first dorsal fin 2.87–3.07; from tip of snout to origin of second dorsal fin 2.01–2.15; from tip of snout to origin of ventral fin 3.09–3.14; from tip of snout to origin of anal fin 1.81–1.84; (numeral represents the ratio of standard length to each item). Snout 3.00; eye 4.06–4.32; interorbital space 2.92–3.07; upper jaw 2.42–2.56; height of second dorsal fin 0.88–0.91; base of the same 0.65–0.66; height of anal fin 1.12–1.35; base of the same 0.77–0.78; pectoral 0.82–0.88; ventral 2.18–2.34; from anterior side side of anus to origin of anal fin 1.92–1.94; length of caudal peduncle 4.46–4.66; depth of the same 6.11–6.28; ventral spine 4.54–4.60; anal spine 4.76–4.94; ratios of head length to each item. ID. VIII; IID. I, 31; A. I, 26; P. i, 21–23; scutes 25.

Body compressed, somewhat oblong in shape. Nape shows gentle inclination. Maxillary reaching front border of eye; lower jaw almost as long as upper jaw. Lateral line only slightly arched, straight from eighteenth soft ray of second dorsal

fin backwards. Scutes relatively small in size, with feeble armature, and present only on posterior two thirds of the straight portion of lateral line. Caudal peduncle has 8 scutes. Anterior regions of second dorsal and anal fins falciform.

Color in formalin grayish brown in dorsal area, becoming paler downward; all the fins grayish but, falcate region of second dorsal fin and distal margins of caudal and ventral fins blackish; several small dusky spots scattered on body side below lateral line (according to Matsubara's observation these are said to be yellowish brown in fresh specimen).

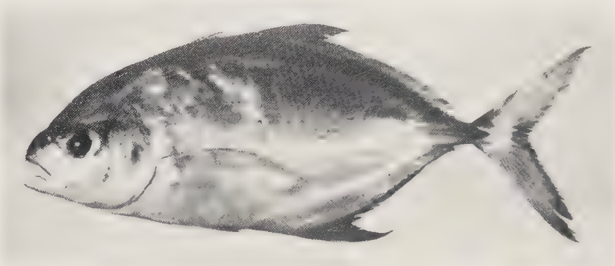

Fig. 59. *Carangoides jordani* Nichols, 245.0 mm in standard length.

Internal:

Material consists of a single specimen, with standard length 245.0 mm and cranial length 52.0 mm.

Rostral length 3.58; diameter of orbit 2.81; postorbital length 2.54; depth 1.68; width 2.00; interorbital width 2.63; ratios between cranial lenght and respective items.

Mesethmoid-vomerine keel low but well-developed. Ventral surface of vomer dentate on a rhomboidal band in its head portion, and with blunt bulge on the midline of its shaft. Superior portion of mesethmoid not protruding from diverging ends of frontals, beneath which it is widened to form a large sinus. Olfactory cavity more or less wide and deep. Lateral expansion of ectethmoid somewhat inconspicuous. Fronto-supraoccipital crest widely expanding, 0.44 time as high as cranium at the center. Supraoccipital occupying about three fourths the dorsal edge of median crest, reaching fore border of orbit. Temporal crest inconspicuous, and much reduced in height in the region of parietal. Ventral surface of parasphenoid with a keel in the region of orbital floor. Pterotic window large, ovate. Posterior spine of pterotic short and blunt. Zygapophyses of exoccipitals meeting each other beneath foramen magnum. Myodome has a narrow posterior foramen. Supramaxillary 0.7 time as long as maxillary. Outer branch of the forked portion of maxillary wider than inner branch. Ascending process of premaxillary relatively high, 0.71 time the entire length of the bone; articular process slightly shorter than ascending process, from which it is separated by a notch; postmaxillary process narrow and bluntly pointed at distal end. Villiform teeth thickly arranged in a narrow

band on lower margin of premaxillary as well as on upper margin of dentary. Anterior two zygapophyses of hyomandibular distinctly apart from each other. Metapterygoid lamina obsolete. Mesopterygoid 0.69 time as long as hyomandibular. Pterygoid wider anteriorly, except with pointed dorso-anterior angle. Palatine with villiform teeth forming a narrow band on ventral surface; prepalatine process relatively large, and indistinguishable from the main part of palatine. Opercle slightly shorter than interopercle. Glossohyal spatulate, and with a narrow band of villiform teeth on dorsal surface in midline. Urohyal proportionately short, shorter than distance from fore end of ceratohyal to posteriormost of epihyal, but longer than ceratohyal wings only slightly expanding. Ceratohyal window nearly oval in shape, located in the middle of longitudinal groove of ceratohyal. Interhyal relatively large. Gill-rakers on first arch $9+21=30$; longest of them 0.56 time the diameter of eye and slightly longer than the corresponding gill-lamella. Main tubercles on the same $5+15=20$; each of them with a ridge, and thickly beset with prickles subequal in size. Preorbital bone wide and flat, 1.3 times as long as wide. Suborbital lamina subtriangular, and 1.8 times as long as wide. External and internal shelves of clavicle make a right angle. Upper member of postclavicle lamellar, and 2.7 times as long as wide; lower member of the same wide, flattened and more or less rhomboidal in upper one third, but rid-like in the other region. Pelvic girdle relatively narrow, and 3.86 times as long as wide. Postpelvic process short, stout, and with forked end. Interpelvic keel slightly developed.

Remarks:

The present specimen is in accord with NICHOLS' (1922) original description except for a trifle discrepancy in the number of scutes, which are 25 in the present specimen instead of 30 in the holotype. A further confirmation based on ample of material would be necessary in order to settle the matter with respect to whether this is due to an individual variation. At any rate, for the present, the author is of the opinion that the present specimen belongs to *Carangoides jordani* NICHOLS. The foregoing description is the first record of this species from the waters adjacent to Japan.

Carangoides hemigymnostethus BLEEKER

Carangoides hemigymnostethus BLEEKER, Nat. Tijds.. Ned. Ind., vol. 1, p. 364, 1851-OSHIMA, Philippine Jour. Sci., vol. 26, no. 3, pp. 388–389, 1925.

Caranx hemigymnostethus GÜNTHER, Cat. Fishes British Mus., vol, 2, p. 438, 1860.

Caranx (Citula) hemigymnostethus WAKIYA, Ann. Carnegie Mus., vol. 15, p. 182, pl. 24, fig. 2, 1924.

Material examined:

1 specimen, 157.0 mm long, at Kuki-ura, Mie Prefecture, 25 June, 1956.
1 specimen, 215.0 mm long, at Izu-Oshima, date unknown.

External:

Depth 2.26–2.33; head 3.39–3.52; from tip of snout to origin of first dorsal fin 2.97–3.12; from tip of snout to origin of second dorsal fin 2.10–2.15; from tip of snout to origin of ventral fin 3.17–3.31; from tip of snout to origin of anal fin 1.74–1.79; (numeral represents the ratio of standard length to each item). Snout 3.75–4.23; eye 3.92; interorbital space 2.81–2.89; upper jaw 2.49–2.55; height of first dorsal fin 4.29–5.08; base of the same 2.44–2.86; height of second dorsal fin 0.89–1.25; base of the same 0.56–0.63; height of anal fin 1.04–1.56; base of the same 0.75–0.79; pectoral 0.75–0.78; ventral 1.86–2.22; from anterior side of anus to origin of anal fin 1.83–1.96; length of caudal peduncle 3.46–4.53; depth of the same 5.30–5.77; ventral spine 3.63–4.29; anal spine 3.98–4.23; ratios of head length to each item. ID. VII-VI; IID. I, 35–33; A. I, 27–26; P. i, 22; scutes 28–25.

Body somewhat high, oblong ovate, and moderately compressed. Dorsal border of head not much inclined, and gently arched. Maxillary extending beyond fore border of eye, but, not reaching the middle of pupil; lower jaw subequal to upper jaw in length. Breast naked. Lateral line slightly arched, but straight from twentith soft ray of second dorsal fin backwards. Scutes small in size, and present only in posterior three-fourths of the straight portion of lateral line. Caudal peduncle with 7 scutes. Second dorsal and anal fins with falciform margin at fore end.

Color in formalin dark brownish in dorsal area, paler downward; fore ends of second dorsal and anal fins blackish; caudal fin with blackish posterior margin; paired fins pale in color; opercular flap with a distinct black spot in its upper part.

Internal:

Material consists of a single specimen, with standard length 215.0 mm and cranial length 50.0 mm.

Rostral length 3.94; diameter of orbit 2.70; postorbital length 2.50; depth 1.47; width 1.85; interorbital width 2.66; ratios of head length to each item.

The present species closely resembles *Carangoides jordani* NICHOLS in general skeletal features, but is different in having the cranial length 3.94 times that of rostral part (3.58 times in *Carangoides jordani*), and in the narrow and long post-pelvic process (stout and short in *C. jordani*).

Genus *Atule* JORDAN and JORDAN

Body somewhat deep, moderately compressed. Scutes well-developed on the straight portion of lateral line extending its entire length. Preorbital region of cranium short and wide. Fronto-supraocciptal crest somewhat high. Myodome very narrow, or absent. Zygapophyses of exoccipitals widely apart from each other beneath foramen magnum. Suborbital lamina small in size, and in contact with first suborbital bone. Suborbital process elongate, aciform. Last three pairs of parapophyses combined together by bony bridges. Inferior vertebral foramina well-developed in last two parapophyses and first haemal spine.

Key to species

1a Posterior aperture of myodome entirely obsolete; superior portion of mesethmoid projecting much beyond frontals so as to yield a strong concavity in dorsal view; supramaxillary much reduced in size, with length one fourth that of maxillary; ascending process of premaxillary longer than articular process; palatine and glossohyal toothless; urohyal without upper anterior process, but with moderately expanded lateral wings; inner side of gill-raker and entire surface of main tubercle sparsely coated with thin, elongate prickles; upper lamellar part of lower member of postclavicle narrower than upper member; interpelvic keel slightly developed············***Atule djeddaba***

1b Posterior aperture of myodome very narrow; superior portion of mesethmoid not protruding from frontals; supramaxillary large in size; ascending process of premaxillary indistinguishable from articular process; palatine and glossohyal dentate; urohyal with somewhat obtuse upper anterior process, and with well-developed lateral wings on posterior half of ventral border; inner side of gill-raker and entire surface of main tubercle thickly beset with minute prickles; upper lamellar region of lower member of postclavicle subequal to upper member in width; interpelvic keel obsolete············***Atule affinis***

Atule djeddaba (FORSKÅL)

Scomber djeddaba FORSKÅL, Descrpt. Animal, p. 56, 1775.

Caranx djeddaba RÜPPELL, Atlas Reise Nordl. Afrika, Fische Rothen Meers, p. 97, pl. 25, fig. 3, 1828-GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 432, 1860-DAY, Fishes India, p. 218, pl. 49, fig. 3, 1878.

Caranx (Selar) djeddaba WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, 1931.

Caranx (Atule) djeddaba WAKIYA, Ann. Carnegie Mus., vol. 15, p. 119, pl. 29, fig. 1, 1924.

Material examined:

5 specimens, Nos. S. 131, S. 704, 27388, 27389, 27390 (Collection of Department of Fisheries, Faculty of Agriculture, Kyoto University), 210.0–179.0 mm long, South China sea, June, 1957, collected by Dr. HIROTOSHI ASANO.

External:

Depth 2.70–2.89; head 3.58–3.74; from tip of snout to origin of first dorsal fin 3.20–3.36; from tip of snout to origin of second dorsal fin 2.04–2.10; from tip of snout to origin of ventral fin 3.67–3.96; from tip of snout to origin of anal fin 1.84–1.89; (numeral represents the ratio of standard length to each item). Snout 4.08–4.58; eye 4.08–4.50; interorbital space 2.84–3.00; upper jaw 3.20–3.56; height of first dorsal fin 2.19-2.68; base of the same 1.67–1.94; height of second dorsal fin 2.01–2.19; base of the same 0.62–0.66; height of anal fin 2.04–2.28; base of the same 0.69–0.76; pectoral 0.81–0.89; ventral 2.10–2.20; from anterior side of anus to origin of anal fin 1.48–1.83; length of caudal peduncle 4.13–4.56; depth of the same 5.40–5.70; ventral spine 3.93–4.20; anal spine 4.20–5.20; ratios of head length

to each item. ID. VIII; IID. I, 25–24; A. I, 21–20; P. i, 21–19; scutes 59–57.

Body elogate, rather slender, comprssed. Dorsal and ventral borders evenly and similarly rounded. Snout blunt, about as long as diameter of eye. Maxillary extending a little beyond fore border of eye; lower jaw somewer jaw somewhat longer than upper jaw. Posterior adipose eyelid, extending to posterior border of pupil. Lateral line strongly curved, and straight below third soft ray of second dorsal fin rearwards; curved portion much shorter and half as long as straight portion. Scutes relatively wide, distinct in entire length of the straight portion of lateral line; widest of them 0.40–0.52 time as wide as diameter of eye.

Color in formalin dark bluish brown, becoming paler downward; first dorsal fin blackish; second dorsal fin grayish, edged with blackish stripes on upper margin; caudal fin grayish; anal and paired fins whitish; opercular flap with a prominent black spot in its upper part.

Internal:

Material consists of a single specimen, with standard length 210.0 mm and cranial length 40.5 mm.

Rostral length 4.77; diameter of orbit 2.53; postorbital length 2.16; depth 1.74; width 1.88; interorbital width 2.53; ratios between cranial length to respective items.

Preorbital region of cranium short and wide. Mesethmoid-vomerine keel inconspicuous, and blunt ridge in the region of mesethmoid. Olfactory cavity rudimentary in its development. Ventral surface of vomer toothless in its head region, and flattened in its shaft. superior portion of mesethmoid protruding far beyond frontals so as to give rise a strong concavity in dorsal view. Outer border of frontal with a comparatively distinct "V"-shaped notch in its anterior part. Fronto-supraoccipital crest wide, 0.3 time as high as cranium. Ventral surface of parasphenoid flat and narrow, shallowy grooved along midline in the region of orbital floor, but obtusely convex in the region of floor of myodome. Posterior perforation of myodome entirely absent. Pterotic window more or less small in size, but distinct. Posterior process of pterotic wide, long, and blunt at the tip. Zygapophyses of exoccipitals widely apart from each other. Supramaxillary much reduced in size, with length one fourth that of maxillary. Maxillary narrowly elongate; outer branch of the forked region not very wide. Ascending process of premaxillary short, with length 0.3 time that of this bone; articular process not exceeding ascending process, from which it is separated by a notch. Lower margin of premaxillary and upper margin of dentary with a single row of sharp conical teeth. Hyomandibular relatively short, 0.52 time as long as cranium; anterior two zygapophyses distinctly apart. Metapterygoid lamina indistinct. Mesopterygoid large, with length 0.74 time that of hyomandibular. Pterygoid not very wide in its fore part, and without dorso-anterior process. Palatine narrow, toothless. Glossohyal small, spatulate in shape, and not toothed on dorsal surface. Urohyal somewhat

narrow, naviculate in shape, describing a gentle curve in its dorso-anterior part, and equal in length to distance from fore end of ceratohyal to hind end of epihyal; lateral wings moderately expanding. Dorsal member of hypohyal inclined inward. Ceratohyal window large, ovoidal in shape, and situated a little in front of the middle of longitudinal groove of ceratohyal. Gill-rakers on first arch 20+5=25; their inner sides sparsely covered with thin, elongate prickles; longest of them 0.43 time the diameter of eye, and shorter than the corresponding gill-lamella. Main tubercles on the same 13+4=17; each of them ridged on surface and sparsely coated with acuminating prickles. Preorbital bone ovate, 1.71 times as long as wide, bulged on surface, and shallowly notched on its posterior. First suborbital bone triangular; second suborbital rod-shaped and the smallest of all the bones constituing orbital chain; third suborbital rectangular; fourth somewhat enlarged and next to preorbital in size. Suborbital lamina small, aliform, and in contact with first suborbital bone. Suborbital process very long, aciform. Clavicle relatively long, 1.08 times as long as cranium; external and internal shelves at a right angle. Upper member of postclavicle flattened, though somewhat narrow; lower member of the same narrow, elongate, and assuming a rib-like appearance in its lower half. Pelvic girdle relatively wide, 3.06 times as long as wide. Postpelvic process 0.29 time as long as girdle, and widely forked. Interpelvic keel little developed.

Remarks:

Fully mature ovary observed in the specimen with standard length 210.0 mm. In the digestive tract of this specimen numerous fragments of crabs were found.

This species is distinguishable from the two allies, *Atule affinis* ((RÜPPELL) and *A. miyakamii* (WAKIYA) by that the supramaxillary is much reduced in size, and by that the inner side of the gill-raker and entire surface of the main tubercle are sparsely covered with thin, elongate prickles.

Atule affinis (RÜPPELL)

Caranx affinis RÜPPELL, Neue Wirbelt., Fische Rothen Meers, p. 49, pl. 14, fig. 1, 1835-EVERMANN and SEALE, Bull. U. S. Bur. Fisheries, vol. 26, p. 64, 1907-JORDAN and RICHARDSON, Bull. U. S. Bur. Fisheries, vol. 27, p. 250, 1908.

Selar affinis JORDAN and STARKS, Ann. Carnegie Mus., vol. 11, p. 443, 1917-OSHIMA, Philippine Jour. Sci., vol. 26, p. 380, 1925.

Caranx (*Atule*) *affinis* WAKIYA, Ann. Carnegie Mus., vol. 15, p. 200, pl. 30, fig. 1, 1924.

Material examined:

2 specimens, Nos. 2704, 3792 (Collection Department of Zoology, Faculty of Science, Tokyo University), 234.0–223.0 mm long, at Palau Islands, 21 October, 1936, collected by Dr. Tokiharu Abe.

1 specimen, 184.0 mm long, at Tsu fish market, Mie Prefecture, 28 September, 1956.

External:

Depth 3.25–3.40; head 3.54–3.86; from tip of snout to origin of first dorsal fin

2.86–3.07; from tip of snout to origin of second dorsal fin 1.94–2.04; from tip of snout to origin of ventral fin 3.20–3.54; from tip of snout to origin of anal fin 1.70–1.74; (numeral represents the ratio of standard length to each item). Snout 2.96–3.25; eye 4.04–4.40; interorbital space 2.95–3.46; upper jaw 2.74–2.76; height of first dorsal fin 1.97–2.19; base of the same 1.89–2.36; height of second dorsal fin 2.19–2.24; base of the same 0.66–0.68; height of anal fin 2.36–2.50; base of the same 0.76–0.82; pectoral 0.82–0.86; ventral 1.97–2.05; from anterior side of anus to origin of anal fin 1.54–1.64; length of caudal peduncle 3.59–3.62; depth of the same 7.80–8.67; ventral spine 3.90–4.96; anal spine 4.96–6.27; ratios of head length to each item. ID. VIII; IID. I, 24; A. I, 21–20; P. i, 22–21; scutes 44–41.

Body elongate, slender, and compressed. Dorsal and ventral borders equally curved. Snout somewhat pointed, longer than diameter of eye. Maxillary reaching fore border of eye; lower jaw longer than upper jaw. Anterior and posterior eyelids well-developed, only partly covering pupil. Lateral line strongly arched, but straight from eighth or ninth soft ray of second dorsal fin rearwards. Scutes large in size, discernible or entire length of the straight portion of that line; largest of them 0.73–0.79 time as wide as diameter of eye. Caudal peduncle with 6 scutes.

Color in formalin dark brownish gray in dorsal area, paler downward; opercular fiap with a prominent black spot in upper region.

Fig. 60. *Atule affinis* (Rüppell), 269.0 mm in standard length.

Internal:

Material consists of a single specimen, with standard length 184.0 mm and cranial length 41.5 mm.

Rostral length 3.77; diameter of orbit 2.96; postorbital length 2.30; depth 2.15; width 2.13; interorbital width 2.96; ratios between cranial length and respective items.

Cranium slightly higher than wide. Preorbital region of cranium short but wide. Mesethmoid-vomerine keel somewhat highly raised. Vomer ventrally convex on midline and with villiform teeth forming a band on ventral surface of its head. Superior portion of mesethmoid neither expanding nor protruding beyond frontals. Olfactory cavity wide and deep. Fronto-supraoccipital crest somewhat highly elevated, 0.37 time as high as cranium at the center. Supraoccipital occupying 0.71 time the dorsal edge of that crest, and extending to the middle of orbit. Pterotic

window somewhat wide. Posterior spine of pterotic triangular and pointing to a sharp end. Opisthotic produced backward into a sharp process. Ventral surface of parasphenoid narrow and flattened in the region of orbital floor, but convex in the region of floor of myodome. Posterior perforation of myodome so narrow as to permit the insertion of a needle. Zygapophyses of exoccipitals widely separated from each other beneath foramen magnum. Supramaxillary large in size, 0.6 time as long as the maxillary. Premaxillary has villiform teeth on a narrow lower marginal band; ascending process coalesced with articular process; postmaxillary process large in size, triangular in form. Dentary has single upper marginal row of villiform teeth; upper arm more or less broad, with width in its middle region subequal to that of lower arm in the same region. Articular with a long ascending process at dorso-posterior corner. Hyomandibular relatively short, 0.46 time as long as cranium; anterior zygapophyses distinctly apart. Metapterygoid lamina obsolete. Mesopterygoid concave on upper surface, and about as long as hyomandibular. Fore part of pterygoid ordinary, and without dorso-anterior process. Palatine subtriangular in lateral aspect, and with large ovoidal band of villiform teeth on inner, lower surface. Interopercle slightly longer than opercle. Glossohyal elongate rectangular, and with a wide band of villiform teeth extending entire length of dorsal surface. Urohyal narrow, its length about same as the distance from fore end of ceratohyal to rear end of epihyal; lateral wings strongly expading in the posterior half of ventral border. Dorsal member of hypohyal not inclined inward. Ceratohyal window wide, ovoidal in form, and situated a little in front of the middle of longitudinal groove of ceratohyal. Gill-rakers on first arch $27+12=39$; longest of them 0.56 time the diameter of eye, and slightly shorter than the corresponding gill-lamella. Main tubercles on the same $20+5=25$; tubercles highly raised to form a ridge, and thickly beset with prickles. Preorbital bone narrow, 2.04 times as long as wide, flat, and shallowly notched on posterior border. First suborbital bone triangular; second suborbital rod-shaped; third suborbital quadrangular; fourth suborbital next to preorbital in size. Suborbital lamina small, aliform and in contact with first suborbital bone. Suborbital process narrowly elongate, assuming an aciform. Posttemporal narrow. Supraclavicle somewhat short, and with disc-like expansion on anterior side at about the middle. Clavicle relatively long, with length 0.9 time that of cranium; external shelf wide, extendlng backward and covering a greater part of internal shelf; the two shelves making an angle of about 60°. Upper member of postclavicle widely flattened; lower member of the same wide and triangular in profile in its upper half, but slender, elongate and aciform in its lower half. Pelvic girdle somewhat narrow, 3.66 times as long as wide. Postpelvic process long, and posteriorly widely forked. Interpelvic keel obliterated.

Remarks:

In the digestive tract of the specimen with standard length 184.0 mm, a crab and numerous fragments of shrimps were discovered.

Atule miyakamii (WAKIYA)

Caranx (Atule) miyakamii WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 201–202, pl. 29, fig. 4, 1924.

Material examined:

1 specimen, 114.0 mm long, at Owase fish market, november, 1957.

External:

Depth 2.60; head 3.80; from tip of snout to origin of first dorsal fin 3.04; from tip of snout to origin of second fin 2.11; from tip of snout to origin of ventral fin 3.68; from tip of snout to origin of anal fin 1.93; (numeral represents the ratio of standard length to each item). Snout 4.11; eye 3.16; interorbital space 3.66; upper jaw 2.60; height of first dorsal fin 2.50; base of the same 2.00; height of second dorsal fin 1.76; base of the same 0.63; height of anal fin 2.17; base of the same 0.65; pectoral 0.86; ventral 2.66; from anterior side of anus to origin of anal fin 1.64; length of caudal peduncle 3.33; depth of the same 5.67; ventral spine 4.48; ratios of head length to each item. ID. VIII; IID. I, 23; A. I, 20; P. i, 19; scutes 37.

Body somewhat deep, strongly compressed. Ventral border more strongly curved than the dorsal. Snout short and blunt, slightly shorter than diameter of eye. Posterior adipose eyelid broad, extending to posterior border of pupil; anterior eyelid also well-developed. Maxillary reaching fore border of pupil; lower jaw slightly longer than upper jaw. Premaxillary on lower margin and dentary on upper margin bear villiform teeth arranged in a narrow band. Vomer and glossohyal also toothed. Lateral line strongly arched, straight from fifth soft ray of second dorsal fin backward; arched region short, 0.52 time as long as straight region. The latter region covered by scutes in entire length. Caudal peduncle with 6 of them. Pectoral fin long, extending to the base of third soft ray of anal fin.

Color in formalin dark grayish brown in dorsal area, becoming paler downward; vertical fins grayish; horizontal fins whitish; opercular flap with a distinct black spot in its upper part.

Internal:

Since only a sole specimen was available, it was impossible to carry out an anatomical study.

Remarks:

The specimen here dealt with agrees quite well with the original description given by WAKIYA (1924) except for some points. Head is 3.16 times as long as diameter of eye instead of 3.78 times in the original description. The pectoral fin extends to the base of the third soft ray of anal fin unlike Wakiya's specimen, which has the pectoral scarcely reaching the origin of anal fin. The author is of the opinion that these differences are merely due to the individual variation and are too trifle to separate them as distinct.

Genus *Kaiwarinus*, new genus

Genotype: *Caranx equula* Temminck and Schlegel

Body high, compressed. Breast has small cycloid scales. Scutes relatively small in size, discernible along entire length of the straight portion of lateral line. Preorbital region of cranium wide, but strongly projecting. Superior portion of mesethmoid ridge-like in appearance, and only slightly extending beyond frontals. Fronto-supraoccipital crest highly elevated. Myodome with a large posterior foramen. Zygapophyses of exoccipitals meeting each other beneath foramen magnum. Ascending process of premaxillary relatively long, and slightly exceeding articular process. Pterygoid neither with anterior expansion, nor with dorsal process. Opercle narrow; its greatest width equaling to that of interoperle. Urohyal gracefully curved on caudal margin, and with lateral wings only slightly expanding. Preorbital bone flattened, nearly triangular in shape. Suborbital lamina large, and in contact with first and second suborbital bones. Suborbital process ensiform, and compressed on the plane perpendicular to suborbital lamina. External shelf more wider than internal shelf. Pelvic girdle relatively narrow; interpelvic keel entirely absent. Last three pairs of parapophyses combined by bony bridges. Inferior vertebral foramina obsolete.

Remarks:

This genus which is nearest to *Caranx* in general features is characterized by having the inferior vertebral foramina obliterated, by the superior porion of mesethmoid neither being widened, nor forming a concavity beneath the fore ends of frontals, and by the ensiform suborbital process which is compressed on the plane perpendicular to the suborbital lamina.

***Kaiwarinus equula* (TEMMINCK and SCHLEGEL)**

Caranx equula Temminck and Schlegel, Pisces, Siebold's Fauna Japonica, p. 111, pl. 60, fig. 1, 1844- Günther, Cat. Fishes British Mus., vol. 2, p. 438, 1860.

Carangoides equula Bleeker, Verh. Batav. Gen., 26, Ichth. van Japan, p. 102, 1857.

Caranx (*Carangoides*) *equula* Wakiya, Ann. Carnegie Mus., vol. 15, p. 166, pl. 19, fig. 3, 1924.

Material examined:

2 specimens, 158.0–154.3 mm long, at Izu-Ôshima, September, 1956.
3 specimens, 174.0–68.0 mm long, at Owase fish market, Mie Prefecture, 15–16 March, 1957.
1 specimen, 143.0 mm long, at Nagasaki fish market, Nagasaki Prefecture, February, 1959.

External:

Depth 1.84–2.19; head 2.83–3.47; from tip of snout to origin of first dorsal fin 2.47–3.05; from tip of snout to origin of second dorsal fin 1.68–2.00; from tip of snout to origin of ventral fin 2.96–3.39; from tip of snout to origin of anal fin 1.70–1.88; (numeral represents the ratio of standard length to each item). Snout 2.89–

3.10; eye 3.12–3.42; interorbital space 2.96–3.23; upper jaw 2.30–2.46; height of first dorsal fin 1.87–2.00; base of the same 1.84–2.12; height of second dorsal fin 1.90–2.18; base of the same 0.68–0.86; height of anal fin 2.06–2.26; base of the same 0.73–0.89; pectoral 085–1.09; ventral 1.76–2.00; from anterior side of anus to origin of anal fin 2.78–3.29; length of caudal peduncle 4.28–6.00; depth of the same 5.10–6.10; ventral spine 4.50–6.30; anal spine 3.22–3.88; ratios of head length to each item. ID. VIII; IID. I, 25–24; A. I, 23–21; P. i, 20–18; scutes 31–28.

Body high, compressed, and rhomboidal in shape. Dorsal border rather strongly curved. Maxillary extending beyond fore border of pupil; lower jaw subequal to upper jaw in length. Adipose eyelid rudimentary. Lateral line arched, but straight from fifteenth or sixteenth soft ray of second dorsal fin backwards. Scutes relatively small, but spinulose, discernible only on the straight portion of the line; largest-sized 0.22–0.25 time as long as diameter of eye. Caudal peduncle with 7 scutes.

Color in formalin dark brown above, paler below; second dorsal and anal fins gray, with a submarginal blackish band, besides with a narrower white marginal band; caudal fin gray, with black margin; pectoral fin whitish; ventral fin grayish, growing darker toward distal part.

Internal:

Material consists of a single specimen, with standard length 174.0 mm and cranial length 25.0 mm.

Rostral length 3.50; diameter of orbit 3.38; postorbital length 3.50; depth 1.78; width 2.33; interorbital width 3.28; ratios between cranial length and respective items.

Mesethmoid-vomerine keel low, but well-developed. Vomer crowded with villiform teeth on a cuneiform area, extending from head to the middle of the bone. Superior portion of mesethmoid much compressed, ridge-like appearance, and slightly protruding forward beyond frontals. Olfactory cavity discernible, wide and shallow. Fronto-supraoccipital crest high, 0.42 time as high as cranium at the center. Supraoccipital occupying posterior two thirds of the median crest, extending to the middle of orbit. Ventral surface of parasphenoid narrow and flattened in the region of orbital floor, but convex in the region of floor of myodome. Posterior perforation of myodome large. Pterotic window closed. Posterior process of pterotic short, but stout, blunt at the tip. Zygapophyses of exoccipitals meeting each other beneath foramen magnum. Supramaxillary 0.61 time as long as maxillary. Ascending process relatively long, 0.55 time as long as premaxillary; articular process slightly shorter than ascending process, from which it is distinguishable by a deep notch; postmaxillary process narrow and blunt at the tip. Two arms of dentary making a right angle. Lower margin of premaxillary and upper margin of dentary beset with teeth thickly arranged in a narrow band. Hyomandibular 0.44 time the cranium in length; anterior two zygapophyses almost fused with each other. Meta-

pterygoid lamina undeveloped. Mesopterygoid relatively large, 0.58 time as long as hyomandibular. Pterygoid not particularly wide in its fore part, and somewhat pointed at its dorso-anterior angle. Palatine large, nearly triangular in lateral aspect, and thickly armed with villiform teeth on a belt-like area along inner, lower surface. Opercle narrow, its greatest width subequal to that of interopercle. Urohyal gracefully curved on posterior margin, and shorter than the distance from fore end of ceratohyal to back end of epihyal; lateral wings slightly expanding. Dorsal member of hypohyal strongly inclined inward. Ceratohyal window large, oval in shape; the region above the window reduced to a very thin osseous continuation. Gill-rakers on first arch 19+8=27; longest of them 0.48 times as long as diameter of eye. Main tubercles on the same 17+4=21; they are strongly bulged and arranged on the arch like a ridge, and thickly beset with minute spinules. Preorbital bone flat, triangular in shape, and with posterior border almost entire. Second and third suborbital bones much narrowed; fourth suborbital somewhat enlarged, twice as long as wide. Suborbital lamina triangular in shape, about as long as wide. Suborbital process slightly longer than twice the suborbital lamina, ensiform, and compressed on the plane perpendicular to lamina. Posttemporal stout, armed at its lower posterior angle with two prominent spines, between which upper part of supraclavicle is inserted. Supraclavicle thick, provided with a longitudinal shallow groove on its outer surface. External shelf of clavicle somewhat wider than internal shelf, the two meeting at a right angle. Upper member of postclavicle lamellar, slightly wider than supraclavicle; lower member of the same lamellar, somewhat wider upward, abruptly narrowing downward in aciform. Pelvic girdle 3.58 times as long as wide. Postpelvic process short and stout, 0.28 time as long as pelvic girdle, and posteriorly widely forked. Interpelvic keel entirely absent.

Remarks:

Within the digestive tract of the specimen 174.0 mm long, three individuals of *Engraulis japonica* (HOUTTUYN) and numerous fragments of shrimps were discovered.

Genus *Longirostrum* WAKIYA

Body oblong, compressed. Scutes small in size, only on the straight portion of lateral line. Preorbital region of cranium elongate. Olfactory cavity well-developed. Superior portion of mesethmoid not exceeding fore ends of frontals, beneath which it is enlarged to form an anteriorly facing concavity. Fronto-supraoccipital crest somewhat high. Myodome with a wide posterior foramen. Zygapophyses of exoccipitals slightly apart from each other beneath foramen magnum. Ascending process of premaxillary long, surpassing articular process, from which it is discriminated by a deep crevice. Pterygoid not particularly wide in its fore part, and without dorso-anterior process. Urohyal almost triangular in lateral aspect; lateral

wings on ventral margin conspicuous only in posterior half. Preorbital bone bulged outward. Suborbital lamina in contact with first and second suborbital bones. External shelf of clavicle backward beyond internal shelf. Pelvic girdle somewhat narrow. Interpelvic keel obsolete. Last two pairs of parapophyses combined by bony bridges. Inferior vertebral foramina entirely absent in any parapophysis and in first haemal spine.

Remarks:

This genus most nearly allied with *Carangoides* in general constitution is distinct from the latter in the zygapophyses of exoccipitals apart from each other, in the urohyal expanding only in the posterior half of the ventral border, in the obliteration of interpelvic keel, and in the same of the inferior vertebral foramina.

Longirostrum delicatissimus (DÖDERLEIN)

Caranx delicatissimus DÖDERLEIN, vol. 3, p. 16, 1884.

Caranx (Longirostrum) delicatissimus WAKIYA, Ann. Carnegie mus., vol. 15, pp. 203–204, pl. 28, fig. 3, 1924.

Material examined:

3 specimens, 227.0–206.0 mm long, at Owase fish market, Mie Prefecture, March, 1958.
2 specimens, 157.0–147.0 mm long, at Izu-Ôshima, 19 August, 1959.
2 specimens, 203.0–147.5 mm long, at Shikine-shima, July, 1960.

External:

Depth 2.83–3.14; head 3.13–3.28; from tip of snout to origin of first dorsal fin 2.66–2.95; from tip of snout to origin of second dorsal fin 1.78–1.96; from tip of snout to origin of ventral fin 2.83–2.96; from tip of snout to origin of anal fin 1.70–1.75; (numeral represents the ratio of standard length to each item). Snout 2.42–2.63; eye 4.37–6.15; interorbital space 2.81–3.26; upper jaw 2.76–2.83; height of first dorsal fin 2.24–2.38; base of the same 1.96–2.08; height of second dorsal fin 2.73–2.98; base of the same 0.76–0.81; height of anal fin 2.81–3.24; base of the same 0.86–0.91; pectoral 1.08–1.15; ventral 2.19–2.38; from anterior side of anus to origin of anal fin 3.21–3.60; length of caudal peduncle 3.12–5.35; depth of the same 6.43–6.92; ventral spine 3.66–4.00; anal spine 6.08–6.83; ratios of head length to each item. ID. VIII; IID. I, 28–25; A. I, 23–21; P. i, 20; scutes 30–24.

Body somewhat narrow, moderately compressed. Dorsal border curved evenly and gracefully from origin of first dorsal fin forward snout end. Snout pointed, much longer than diameter of eye. Maxillary scarcely reaching fore border of eye; lower jaw slightly shorter than upper jaw. Lateral line strongly arched, but straight from thirteenth soft ray of second dorsal fin backwards. Scutes small in side, with feeble armature, and found on posterior three fourths of the straight portion of the line.

Color in formalin grayish black in dorsal area, growing paler downward; two

dorsal and caudal fins grayish; pectoral, ventral and anal fins whitish; opercular flap spotted with a black marking in upper part.

Internal:

Material consists of a single specimen, with standard length 227.0 mm and cranial length 25.0 mm.

Rostral length 3.15; diameter of orbit 3.28; postorbital length 2.30; depth 1.80; width 2.19; interorbital width 3.04; ratios between cranial length and respective items.

Mesethmoid-vomerine keel low. Vomer toothless; ventral surface of median shaft convex, but shallowly grooved on the midline. Superior portion of mesethmoid retreating from fore ends of frontals, beneath which it shows large anterior sinus. Olfactory cavity wide and deep. Fronto-supraoccipital crest somewhat highly ridged, 0.32 time as high as cranium at the center. Supraoccipital occupying posterior three fifths of the median crest and extending a little in front of the middle of orbit. Ventral surface of parasphenoid narrow and flat in the region of orbital floor, but moderately round in the region of floor of myodome. Posterior opening of myodome large, quadrangular. Zygapophyses of exoccipitals a little apart from each other beneath foramen magnum. Supramaxillary 0.6 time as long as maxillary. Premaxillary with ascending process 0.62 time as long as its own length; articular process slightly shorter than ascending process, the two separable by a deep notch; postmaxillary process narrow but long, bluntly at the tip. Lower surface of premaxillary and upper surface of dentary with a single row of conical teeth. Hyomandibular 0.43 time as long as cranium; anterior two zygapophyses very in close contact with each other. Metapterygoid lamina entirely absent. Mesopterygoid proportinally large in size, 0.76 time as long as hyomandibular. Fore part of pterygoid somewhat wide, but lacking in dorso-anterior process. Palatine large, triangular in lateral aspect, showing a thick arrangement of villiform teeth in a narrow band on anterior half of lower surface. Glossohyal narrow, sapatulate in shape, and not armed with teeth. Urohyal nearly triangular, with a sharp dorso-anterior angle, and with lateral expansion only in posterior half of ventral border; its length only slightly larger than ceratohyal. Ceratohyal window large, in the middle of longitudinal groove of the bone. Gill-rakers on first arch $24+12=36$; longest of them 0.67 time as long as diameter of eye, and slightly shorter than the corresponding gill-lamella. Main tubercles on the same $20+5=25$, strongly bulged and arranged on the arch like a ridge, each densely granuated instead of being thorny. Preorbital bone flat, ovoidal in shape, somewhat notched on posterior margin, and 1.5 times as long as wide. First suborbital bone somewhat triangular; second and third suborbitals much narrower, but fourth again wider. Suborbital lamina large, 1.2 times as long as wide, in contact with first and second suborbital bones. Suborbital process rod-like, slightly shorter than suborbital lamina. Posttemporal with two prominent lower posterior spines, between which upper part of

supraclavicle is inserted. Supraclavicle narrow, with a longitudinal shallow groove on outer surface. Clavicle 0.9 time as long as cranium, with wide external shelf, covering a greater part of internal shelf; the angle which the two shelves interpose somewhat less than 90°; anterior shelf on anterior margin of clavicle moderate in development. Hypocoracoid triangular, with a large foramen at its center. Lower member of postclavicle lamellar and elongate rhomboidal in shape in its upper part, but abruptly narrowing downward into a thin needle. Pelvic girdle 3.5 times as long as wide. Postpelvic process divided into a fork in its posterior half. Interpelvic keel obsolete.

Remarks:

In addition to this species, *Longirostrum platessa* (Cuvier and Valenciennes) and *L. mertensi* (Cuvire and Valenciennes) were recorded from the water adjacent to Japan by Wakiya (1924). Despite his careful sertification the present author was unable to obtain the specimens referable to these species. On examining literature cited Wakiya carefully, he reached the conclusion that *L. platessa* is distinct from the other two species in being the dorsal border of head slightly concave above the nostrils, and that *L. mertensi* is peculiar in having the smaller number of scutes and the pectoral fin much shorter than the depth of body.

Genus *Trachurops* Gill

Scutes discernible on entire length of the straight portion of lateral line. Cranium deep, strongly bulged laterally in the region of pterotics. Mesethmoid-vomerine keel highly elevated, assuming an appearance of thin plate. Olfactory cavity narrow but deep. Fronto-supraoccipital crest somewhat high. Posterior perforation of myodome wide. Zygapophyses of exoccipitals widely apart from each other. Ascending process of premaxillary blunt at the tip, not exceeding articular process; postmaxillary process narrow, sharp, and projecting dorso-posteriorly. Mesopterygoid large in size. Pterygoid not particularly wide in its fore part. Interopercle sinuate on posterior margin. Length of urohyal much longer than the distance from fore end of ceratohyal to rear end of epihyal; lateral wings well-developed along entire length of ventral border. Preorbital bone bulged on surface, round in dorso-anterior view. Third and fourth suborbital bones more or less wide. Suborbital lamina in contact with first and second suborbital bones. Suborbital process short, aciform. External and internal shelves interposing at a right angle. Pelvic girdle wide, and without interpelvic keel. Last four pairs of parapophysee combined by bony bridges. Inferior vertebral foramina well-developed only at the base of first haemal spine.

Remarks:

The present genus has a certain affinity to *Atule* in general constitution, but is distinct in the high mesethmoid-vomerine keel which is a plate-like in appearance,

in the deep and narrow olfactory cavity, in the premaxillary, the ascending process of which does not surpass the articular process, and in the absence of the inferior vertebral foramina in any of the parapophyses.

Trachurops crumenophthalmus (Bloch)

Scomber crumenophthalmus Bloch, Naturges. Ausland, Fische, vol. 7, p. 77, pl. 243, 1793.

Caranx crumenophthalmus Lacépède, Hist. Poissons, vol. 4, p. 107, 1902-Günther, Cat. Fishes British Mus., vol. 3, p, 429, 1860-Day, Fishes India, p. 217, pl. 49, fig. 1, 1878.

Caranx mauritianus Quoy and Gaimard, Voy. Uranie, Zoologie, p. 359, 1824-Cuvier and Valenciennes, Hist. Nat. Poissons, vol. 9, p. 60, 1833.

Caranx macrophthalmus Rüppell, Atlas Reise Nordl. Afrika, Fische Rothen Meers, p. 97, pl. 25, fig. 4, 1828.

Trachurops crumenophthalmus Gill, Proc. Acad. Nat. Sci. Phila., vol. 14, 1863.

Trachurops crumenophthalma Jordan and Evermann, Bull. U. S. Fish. Comm., vol. 23, part 1, p. 187, fig. 71, 1905-Jordan and Richardson, Bull. U. S. Fisheries, vol. 27, p. 250, 1908-Oshima, Philippine Jour. Sci., vol. 26, p. 369, 1925.

Trachurops mauritianus Jordan and Hubbs, Mem. Carnegie Mus., vol. 10, p. 223, 1925.

Selar crumenophthalmus Fowler, Copeia, no. 58, p. 63, 1918-Fowler, Proc. Acad. Nat. Sci. Phila., vol. 79, p. 269, 1927-Barnard, Ann. South African Mus., vol. 21, p. 536, 1927-Fowler, Mem. Bishop Mus., vol. 10, p. 144, fig. 37, 1928.

Selar mauritianus Wakiya, Ann. Carnegie Mus., vol. 15, pp. 159–160, pl. 18, fig. 2, 1924.

Selar macrophthalmus Wakiya, Ann. Carnegie Mus., vol. 15, pp. 160–161, pl. 18, fig. 3, 1924.

Material examined:

3 specimens, 190.5–168.5 mm long, at Kuki-ura, Mie Prefecture, November, 1957.
2 specimens, 196.0–179.0 mm long, at Tsu fish market, Mie prefecture, 4 October, 1958.

External:

Depth 3.36–3.73; head 3.36–3.66; from tip of snout to origin of first dorsal fin 2.88–3.06; from tip of snout to origin of second dorsal fin 1.87–1.96; from tip of snout to origin of ventral fin 3.20–3.28; from tip of snout to origin of anal fin 1.70–1.76; (numeral represents the ratio of standard length to each item). Snout 3.25–3.73; eye 3.06–3.40; interorbital space 3.46–3.77; upper jaw 2.13–2.34; height of first dorsal fin 1.95–2.10; base of the same 1.90–2.13; height of second dorsal fin 2.12–2.36; base of the same 0.74–0.79; height of anal fin 2.20–2.54; base of the same 0.83–0.91; pectoral 1.00–1.14; ventral 1.87–1.96; from anterior side of anus to origin of anal fin 2.19–2.38; length of caudal peduncle 4.40–5.14; depth of the same 5.36–6.15; ventral spine 3.65–3.96; anal spine 4.58–4.89; ratios of head length to each item. ID. VIII; IID. I, 26–24; A. I, 22–21; P. i, 20–19; scutes 36–30.

Body somewhat high, moderately compressed. Depth about twice the width or slightly less. Eye large, with diameter equal to snout length or slightly larger. Maxillary extending to fore border of pupil; lower jaw longer than upper jaw. Lateral line slightly arched, straight from twelfth soft ray of second dorsal fin backward. Scutes large, present almost in entire length of lateral line; longest of them

0.46–0.48 time the eye diameter.

Color in formalin dark brownish in dorsal area, paler in ventral area; first and second dorsal fins dusky; caudal fin dusky, edged with black band caudally; other fins whitish.

Internal:

Material consists of a single specimen, with standard length 183.0 mm and cranial length 44.5 mm.

Rostral length 4.04; diameter of orbit 2.54; postorbital length 2.78; depth 1.98; width 2.02; interorbital width 3.56; ratios between cranial length and respective items.

Cranium strongly bulged laterally in the region of pterotics. Mesethmoid-vomerine keel raised into a plate. Vomer narrow and flattened in shaft and with a small ovoidal band of villiform teeth on ventral surface on each side of head. Olfactory cavity very narrow, but well-developed. Lateral orbital expansion of ectethmoid distinct. Fronto-supraoccipital crest more or less high, 0.22 time as high as cranium at the center. Ventral surface of parasphenoid narrow and flat in the region of orbital floor, but moderately round in the region of floor of myodome. Myodome with a wide posterior foramen. Pterotic window absent. Posterior process of pterotic short, thick and stout. Zygapophyses of exoccipital widely apart from each other beneath foramen magnum. Supramaxillary 0.62 time as long as maxillary. Outer branch of maxillary fork small in size, with length smaller than width of posterior region; inner branch with a small perforation in the middle. Premaxillary with a narrow band thickly beset with villiform teeth; ascending process 0.36 time the entire length of the bone, and surpassed by articular process in length; postmaxillary process narrow and sharp. Dentary with a single series of villiform teeth on upper margin; upper arm sharply pointed at the tip, straightened on lower border, and making an angle about 60° with lower arm. Hyomandibular somewhat short, 0.44 time as long as cranium; anterior two zygapophyses distinctly apart. Metapterygoid lamina obsolete. Mesopterygoid slightly longer than hyomandibular. Pterygoid almost straightened on lower margin and not enlarged in fore part. Palatine stout, triangular in lateral aspect, provided with a narrow band of villiform teeth on lower surface. Interopercle relatively wide, strongly concave on posterior margin. Glossohyal spatulate, armed with a narrow band of villiform teeth extending entire length of dorsal surface. Urohyal low, naviculate in lateral aspect, acutely projecting at its dorso-anterior corner, and with strong lateral expansions; its length smaller than the length of hyoid body, but larger than the distance from fore end of ceratohyal to hind end of epihyal. Ceratohyal window large, oblong ovate in shape, and situated in the middle of longitudinal groove of ceratohyal. Interhyal somewhat thin, 0.7 time as long as glossohyal. Gill-rakers on first arch 28+10=38; longest of them 0.55 time as long as diameter of eye. Main tubercles on the same 20+4=24; each of them strongly bulged. Preorbital

bone bulged on surface, projecting dorso-anteriorly in a round lobe, slightly notched on posterior margin, and 1.63 times as long as wide. First suborbital bone wide, quadrangular in shape; second suborbital much narrower; third and fourth suborbitals again wider. Suborbital lamina wide, 1.4 times as long as wide, and in contact with first and second suborbital bones. Suborbital process short but sharp. Posttemporal wide. Supraclavicle narrow, with disc-like expansion at about the middle of its anterior side. Clavicle 0.85 time as long as cranium; external and internal shelves forming together a right angle. Upper member of postclavicle wide and lamellar; lower member of the same somewhat wide in its upper half, abruptly narrowing downward in a form of a rib. Pelvic girdle 3.28 times as long as wide. Postpelvic process sharply projecting, slightly forked at posterior end. Interpelvic keel obliterated.

Remarks:

The specimen 183.0 mm long collected at Kuki-ura contained in the digestive tract 6 individuals of *Engraulis japonica* (Houttuyn) and numerous fragments of shrimps and crabs.

At the opportunity he made the revision of the Japanese carangids, Wakiya (1924) recorded *Trachurops mauritianus* (Quoy and Gaimard), *T. macrophthalmus* (Rüppell) and *T. torvus* (Jenyns) from the seas adjacent to Japan. The present study confirms the fact that the former two are both synonymous with *T. crumenophthalmus* (Bloch), and the last is distinguishable from *crumenophthalmus* in the upper jaw having the teeth arranged on a single row.

Genus *Trachurus* Rafinesque

Scutes large, discernible along entire length of lateral line. Preorbital region of cranium somewhat narrowly projecting. Olfactory cavity well-developed. Fronto-supraoccipital crest relatively low. Lateral surface of myodome bulged outward and formed by prootic, basioccipital and exoccipital. Posterior opening of myodome wide. Zygapophyses of exoccipitals a little apart from each other beneath foramen magnum. Ascending process of premaxillary blunt at the tip, shorter than articular process; postmaxillary process narrow and sharp. Mesopterygoid large in size. Pterygoid not particularly wide in its fore part. Preorbital bone elongate elliptical in shape, bulged on surface. Third and fourth suborbital bones wide. Suborbital lamina narrow in area, and in contact with first and second suborbital bones. Suborbital process aciform. External shelf of clavicle wider than internal shelf, the two making together an angle slightly smaller than 90°. Pelvic girdle widened. Interpelvic keel undeveloped. Last three pairs of parapophyses combined by bony bridges. Inferior vertebral foramina entirely absent in any parapophysis and in first haemal spine.

Trachurus japonicus (TEMMINCK and SCHLEGEL)

Caranx trachurus japonicus TEMMINCK and SCHLEGEL, p. 109, pl. 59, fig. 1, 1844.
Trachurus japonicus WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 144–145, 1924.
Trachurus argenteus WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 145–146, 1924.

Material examined:

20 specimens, 83.0–62.5 mm long, at Yonezu, Tsu City, Mie Prefecture, 6–10 July, 1957.
21 specimens, 153.0–50.0 mm long, at Owase fish market, Mie Prefecture, 5 August, 1957.
4 specimens, 250.0–228.5 mm long, at Koga, Mie prefecture, 18, February, 1958.

External:

Depth 3.72–4.16; head 3.13–3.83; from tip of snout to origin of first dorsal fin 2.66–3.07; from tip of snout to origin of second dorsal fin 1.81–1.98; from tip of snout to origin of ventral fin 3.02–3.31; from tip of snout to origin of anal fin 1.68–1.80; (numeral represents the ratio of standard length to each item). Snout 2.90–3.54; eye 2.80–3.47; interorbital space 3.14–4.04; upper jaw 2.55–2.59; height of first dorsal fin 1.81–2.35; base of the same 1.81–2.16; height of second dorsal fin 1.93–2.24; base of the same 0.70–0.76; height of anal fin 2.07–2.34; base of the same 0.78–0.87; pectoral 0.90–1.46; ventral 1.55–1.94; from anterior side of anus to origin of anal fin 3.05–4.40; length of caudal peduncle 3.92–7.75; depth of the same 6.07–8.00; ventral spine 2.83–4.06; anal spine 3.50–5.43; ratios of head length to each item. ID. VIII; IID. I, 30–35; A. I, 26–30; P. i, 17–22; scutes 68–74.

Body low, moderately compressed. Snout somewhat pointed, with length subequal to diameter of eye or slightly less. Maxillary extending beyond fore border of eye; lower jaw longer than upper jaw. Lateral line strongly arched, straight from eighth soft ray of second dorsal fin backward. Scutes well-developed, present on entire length of lateral line; largest of them on the curved portion same as that on the straight portion in caliber or somewhat less.

Color in formalin dark grayish black above (somewhat paler and brownish black in the specimens collected at Yonezu), whitish below; first and second dorsal fins and caudal fin brownish; anterior part of second dorsal fin white; anal and paired fins paler; opercular flap with a distinct black spot in its upper part.

Internal:

Material consists of a single specimen, with standard length 225.0 mm and cranial length 47.0 mm.

Rostral length 3.63; diameter of orbit 2.73; postorbital length 2.77; depth 2.10; width 2.16; interorbital width 3.63; ratios between cranial length and respective items.

Preorbital region of cranium somewhat narrowly projecting. Mesethmoid-vomerine keel low, but well-developed. Ventral surface of vomer with a small ovoidal band of villiform teeth on each side of its head, and provided with a serrated longitudinal crest along midline of shaft. Superior portion of mesthmoid re-

treating from fore end of frontals. Olfactory cavity well-developed. Fronto-supraoccipital crest relatively low, 0.22 time as high as cranium at the center. Supraoccipital occupying posterior half of median crest, and extending somewhat behind the middle of orbital cavity. Ventral surface of parasphenoid narrow and flat in the region of orbital floor, but moderately bulged in the region of floor of myodome. Lateral surface of myodome formed by prootic, basioccipital and exoccipital strongly bulging outward. Pterotic window widely open. Pterotic crest highly raised, but relatively short. Posterior process of pterotic ensiform. Myodome with wide opening at the posterior bifurcated end of parasphenoid. Zygapophyses of exoccipitals apart from each other beneath foramen magnum. Supramaxillary 0.54 time as long as maxillary. Outer branch of maxillary fork small in size, about half as wide as posterior region of maxillary; inner branch with a small foramen at its center. Premaxillary armed with two or three rows of villiform teeth on lower margin, except at extreme fore end, where a single row is found; ascending process short, blunt at the tip, and strongly surpassed by articular process; postmaxillary process long, and somewhat triangular. Dentary with a single row of villiform teeth on upper margin; upper and lower arms making a right angle. Hyomandibular relatively short, 0.4 time as long as cranium; anterior two zygapophyses distinctly apart. Metapterygoid lamina undeveloped. Mesopterygoid large in size, 1.1 time as long as hyomandibular, and concave on upper surface. Pterygoid not particularly wide in its fore part. Palatine somewhat slender, and with a single row of villiform teeth on lower surface. Glossohyal narrow, rod-shaped, with villiform teeth on dorsal surface. Urohyal naviculate, acutely pointed at dorso-anterior corner, and provided on ventral border in its entire length with conspicuous lateral expansion; the bone is longer than ceratohyal, but shorter than the distance from fore end of ceratohyal to hind end of epihyal. Ceratohyal window wide, ovoidal in shape. Gill-rakers on first arch $40+14=54$; longest of them half as long as diameter of eye. Main tubercles on the same $25+9=34$; each of them highly raised. Preorbital bone elongate oval in shape, bulged outward on surface, with a deep notch on posterior border, and 1.9 times as long as wide. Second suborbital bone much narrowed, third suborbital somewhat wider, 2.3 times as long as wide; fourth suborbital again wider, 1.3 times as long as wide. Suborbital lamina small in size, and in contact with first and second suborbital bones. suborbital process aciform. Posttemporal relatively small in size. Supraclavicle slender, elongate, and with a conspicuous triangular process on fore border. Clavicle 0.95 time as long as cranial length; external shelf wider than internal shelf, the two making an acute angle; anterior shelf well-developed. Dorsal member of postclavicle wide and flat; ventral member of the same elongate rhombic in shape in its upper half, but abruptly narrowed into a slender rib in its lower half. Pelvic girdle thrice as long as wide. Postpelvic process forked into sharp processes at posterior end. Interpelvic keel obsolete.

Remarks:

WAKIYA (1924) recorded *Trachurus argenteus* WAKIYA and *T. declivis* (JENYNS) together with the present species from Japanese waters. Of these, the first is, without doubt, synonymous with the last, but the second is distinct in having the head length equal to the depth of body.

Genus *Decapterus* BLEEKER

Second dorsal and anal fins have each a finlet behind. Scutes present only on the straight portion of lateral line. Preorbital region of cranium strongly produced. Olfactory cavity well-developed. Fronto-supraoccipital crest very low. Myodome with wide or narrow perforation at posterior end. Zygapophyses of exoccipitals widely apart from each other beneath foramen magnum. Ascending process of premaxillary blunt at the tip, and shorter than articular process. Fore part of pterygoid not particularly wide. Preopercle conspicuously produced backward into a linguiform lobe. Opercle shorter than interopercle. Urohyal slightly longer than or about as long as hyoid body, and with broad lateral wings along entire length of ventral border. Preorbital bone ovate and with bulged surface. Third and fourth suborbital bones wide. Suborbital lamina narrow, and in contact with first suborbital bone. External shelf of clavicle greatly enlarged in area, meeting with internal shelf at 45°, and largely covering the latter in lateral aspect. Pelvic girdle wide, and without interpelvic keel. Bony bridge absent from any pair of parapophysis. Inferior vertebral foramina present at the base of first haemal spine.

Remarks:

The present genus is most nearly allied to *Trachurus*, but is distinguishable chiefly by having a finlet behind the second dorsal and the anal fins, by the presence of scutes on the staright portion of lateral line, and by the elongate urohyal.

Key to species

1a Median shaft of vomer with medio-ventral toothed crest.
 2a Dorsal and ventral arms of dentary at an acute angle.
  3a Vomer with a rhomboidal band of villiform teeth in its head portion on ventral surface; premaxillary with a single row of teeth on lower margin; glossohyal spatulate, and not toothed············***Decapterus russellii***
  3b Vomer with a small ovoidal band of villiform teeth in its head portion on ventral surface; premaxillary toohless; glossohyal rod-shaped, and with villiform teeth on dorsal surface············***Decapterus lajang***.
 2b Dorsal and ventral arms of dentary at a right angle.
  4a Vomer with a small ovoidal band of villiform teeth in its head portion on each side of ventral surface; dorsal margin of fronto-supraoccipital crest with a notch at the boundary between frontal and supraoccipital regions;

gill-rakers on first arch 51; main tubercles on the same 32 ....***Decapterus maruadsi***

4b Vomer toothless in its head portion on ventral surface; dorsal margin of front-supraoccipital crest entire; gill-rakers on first arch 38; main tubercles on the same 21............***Decapterus akaadsi***

1b Median shaft of vomer without toothed medio-ventral crest.

5a Median shaft of vomer with a shallow mid-ventral groove; mesethmoid-vomerine keel well-developed; postpelvic process forked at posterior end ....***Decapterus muroadsi***

5b Median shaft of vomer without mid-ventral groove; mesethmoid-vomerine keel present only in the region of vomer; postpelvic process not ending in a fork............***Decapterus macrosoma***

Decapterus russellii (RÜPPELL)

Caranx russellii Rüppell, Atlas Reise Nordl. Afrika, Fische Rothen Meeres, p. 99, 1828.

Caranx kurra Cuvier and Valenciennes, Hist. Nat. Poissons, vol. 9, p. 44, 1833-Günther, Cat. Fishes British Mus., vol. 2, p. 427, 1860-Day, Fishes India, p. 214, pl. 48, fig. 5, 1878.

Decapterus kurra Bleeker, Nat. Tijids. Ned. Ind., vol. 1, p. 358, 1851-Fowler, Copeia, no. 58, p. 63, 1918-Oshima, Philippine Jour. Sci., vol. 26, p. 359, 1925-Fowler, Proc. Akad. Nat. Sci. Phila., vol. 79, p. 268, 1927.

Decapterus russellii Weber, Siboga-Exped., vol. 57, Fische, p. 393, 1913-Ogilby, Mem. Queensland Mus., vol. 3. p. 59, 1915-Wakiya, Ann. Carnegie Mus., vol. 15, p. 149, pl. 15, fig. 2, 1924-Barnard, Ann. South African Mus., vol. 5, p. 184, 1929-Weber and de Beaufort, Fishes Indo-Australian Archipelago, vol. 6, p. 196, fig. 41, 1931.

Material examined:

3 specimens, 316.0–294.0 mm long, at Toba, Mie Prefecture, 15 October, 1953.
2 specimens, 306.0–300.0 mm long, at Owase fish market, Mie Prefecture, 6–7 November, 1955.

External:

Depth 4.58–4.77; head 3.33–3.46; from tip of snout to origin of first dorsal fin 2.63–2.70; from tip of snout to origin of second dorsal fin 1.78–1.85; from tip of snout to origin of ventral 3.04–3.36; from tip of snout to origin of anal fin 1.45–1.56; (numeral represents the ratio of standard length to each item). Sonut 2.96–3.19; eye 4.48–4.60; interorbital space 3.57–4.52; upper jaw 2.84–3.04; height of first dorsal fin 2.02–2.15; base of the same 1.97–2.16; height of second dorsal fin 2.46–2.58; base of the same 0.75–0.81; height of anal fin 3.14–3.19; base of the same 1.09–1.14; pectoral 1.36–1.38; ventral 2.50–2.58; from anterior side of anus to origin of anal fin 3.50–4.25; length of caudal peduncle 3.26–3.34; depth of the same 9.30–10.00; ventral spine 5.83–5.95; anal spine 5.00–5.08; ratios of head length to each item. ID. VIII; IID. I, 31–32; A. I, 23–24; P. i, 21; scutes 43–40.

Body fusiform, and not compressed. Snout length 1.5 times as long as eye diameter. Interorbital space slightly wider than, or about equal to diameter of eye. Maxillary scarcely reaching front border of eye; lower jaw slightly longer than

upper jaw. Lateral line only slightly arched, straight from fourteeth soft ray of second dorsal fin backward. Scutes present on posterior two thirds of the straight portion of lateral line; largest of them 0.43–0.52 time as wide as diameter of eye.

Color in formalin dark bluish black above, paler below; first and second dorsal fins and caudal fin dusky; other fins somewhat whitish; opercular flap spotted with a distinct black marking in its upper part.

Internal:

Material consists of a single specimen, with standard length 243.0 mm and cranial length 54.0 mm.

Rostral length 3.37; diameter of orbit 3.60; postorbital length 2.44; depth 2.72; with 2.48; interorbital width 4.00; ratios between cranial length and respective items.

Cranium slender, and wider than high. Mesethmoid-vomerine keel low but well-developed. Vomer with villiform teeth in head portion on ventral surface, and provided on midline of the median shaft with a low longitudinal crest bearing a single row of teeth on ventral edge. Superior of mesethmoid neither widened, nor protruding from fore ends of frontals. Lateral orbital expansion of ectethmoid conspicuous. Fronto-supraoccipital crest very low, 0.07 time as high as cranium at the center. Supraoccipital occupying 0.6 time the dorsal edge of median crest, reaching a little in front of the posterior border of orbit. Ventral surface of parasphenoid narrow and flat in the region of orbital floor, but moderately round in the region of myodome. Posterior opening of myodome narrow, slit-like in profile. Posterior process of pterotic subtriangular in form. Zygapophyses of exoccipitals widely apart from each other beneath foramen magnum. Supramaxillary 0.7 time as long as maxillary. Outer branch of maxillary fork very small in size, about half as wide as posterior region of maxillary. Ascending process of premaxillary low, 0.3 time as long as the bone; articular process exceeding ascending process; postmaxillary process narrow and large, extending dorso-posteriorly. Lower margin of premaxillary and upper margin of dentary with a single series of villiform teeth. Hyomandibular short, 0.36 time as long as cranium; anterior two zygapophyses distinctly apart from each other. Metapterygoid lamina obsolete. Mesopterygoid large, 1.5 times as long as hyomandibular. Fore part of pterygoid neither particularly wide nor produced into a process. Palatine with a narrow band somewhat sparsely beset with villiform teeth on lower, inner surface. Opercle shorter than interopercle. Glossohyal relatively large, spatulate in shape, and not toothed on dorsal surface. Urohyal large, naviculate, and only slightly shorter than distance from anterior end of hypohyal to posterior end of epihyal; lateral wings conspicuous. Ceratohyal window large, ovoidal in shape, and situated a little in front of the middle of longitudinal groove of ceratohyal. Interhyal small, shorter than one third of glossohyal. Gill-rakers on first arch $31+12=43$; longest of them 0.57 time the diameter of eye, and slightly shorter than the corresponding gill-lamella. Main tubercles on

the same 19+6=25; each of them well bulged. Preorbital bone elongate ovate, 2.08 times as long as wide, strongly bulged on surface, and with a deep "V"-shaped notch on posterior border. First suborbital bone more or less ovate; second suborbital much narrowed; third and fourth suborbitals much enlarged in area. Suborbital lamina narrow, and in contact with first and second suborbital bones. Posttemporal very low; dorsal branch much longer than ventral branch. Clavicle 0.7 time as long as cranium; external shelf greatly expanding, meeting internal shelf at 45°, and covering the greater part of the latter in lateral aspect. Dorsal member of postclavicle wide and lamellar; ventral member of the same somewhat broader in upper part, but slenderer like a rib in lower part. Pelvic girdle 2.6 times as long as wide. Postpelvic process undivided at posterior end. Interpelvic keel undeveloped.

Remarks:

The digestive tract of the specimen 306.0 mm long collected at Owase, contained fish muscles, Euphausia and Isopoda.

Decapterus lajang BLEEKER

Decapterus lajang Bleeker, Nat. Tijids. Ned. Ind., vol. 8, p. 302, 1855-Günther, Fishes British Mus., vol. 2, p. 423, 1860-Wakiya, Ann. Carnegie Mus., vol. 15, p. 155, pl. 17, fig. 1, 1924-Barnard, Ann. South African Mus., vol. 21, p. 535, 1925–27-Weber and de Beaufort, Fishes Indo-Australian Archipelago, vol. 6, p. 200, 1931-Nichols, American Mus., Nat. Hist. Novitates, no. 1196, p. 4, 1942.

Material examined:

5 specimens, 235.0–243.0 mm long, at Shimoda, Shizuoka Prefecture, 7 April, 1954.
4 specimens, 246.0–242.0 mm long, at Owase, Mie Prefecture, November, 1957.

External:

Depth 4.86–5.55; head 3.80–4.16; from tip of snout to origin of first dorsal fin 2.92–3.08; from tip of snout to origin of second dorsal fin 1.85–1.94; from tip of snout to origin of ventral fin 3.78–3.98; from tip of snout to origin of anal fin 1.60–1.67; (numeral represents the ratio of standard length to each item). Snout 3.12–3.32; eye 4.05–4.16; interorbital space 3.66–3.80; upper jaw 2.62–2.86; height of first dorsal fin 1.83–1.91; base of the same 1.68–1.79; height of second dorsal fin 2.26–2.86; base of the same 0.63–0.66; height of anal fin 2.54–2.86; base of the same 0.78–0.75; pectoral 1.39–1.50; ventral 2.20–2.24; from anterior side of anus to origin of anal fin 3.65–3.97; length of caudal peduncle 3.03–3.22; depth of the same 7.17–7.50; ventral spine 5.30–5.68; anal spine 4.70–4.76; ratios of head length to each item. ID. VIII; IID. I, 36–34; A. I, 30–28; P. i, 21–20; scutes 28–30.

Body elongated, fusiform, and scarcely compressed. Lower jaw subequal to upper jaw in length; maxillary barely reaching fore border of eye. Lateral line slightly arched, but straight from fourteenth or fifteenth soft ray of second dorsal fin backwards. Scutes distinct on posterior two thirds of the straight portion of

lateral line; largest of them 0.43–0.52 time as long as diameter of eye.

Color in formalin dark bluish in dorsal area, becoming paler downward; first and second dorsal fins and caudal fin dusky; anal and paired white; opercular flap with a prominent black spot in its upper part.

Internal:

Material consists of a single specimen, with standard length 243.0 mm and cranial length 54.0 mm.

Rostral length 3.37; diameter of orbit 3.37; postorbital length 2.51; depth 2.63; width 2.40; interorbital width 3.86; ratios between cranial length and respective items.

Cranium somewhat elongate, wider than high. Mesethmoid-vomerine keel more or less high. Superior portion of mesethmoid not widend in the region inserted between frontals. Olfactory cavity wide and deep. Ventral surface of vomer with a small ovoidal band of villiform teeth on each side of head portion; the bone with a somewhat sharp crest armed by a single row of teeth in shaft region. Fronto-supraoccipital crest very low, 0.09 time as high as cranium at the center. Ventral surface of parasphenoid narrow and flat in the region of orbital floor, but convex in the region of floor of myodome. Pterotic window large, nearly circular in shape. Posterior process of pterotic long and sharp. Exposed part of opisthotic long, sharply pointing backward in dorsal aspect, and with an accessory spine at the base. Zygapophyses of exoccipitals widely apart. Myodome with a large posterior foramen. Supramaxillary 0.7 time as long as maxillary. Maxillary round at ventro-posterior corner. Premaxillary devoid of teeth on lower margin; ascending process 0.37 time as long as the bone and much shorter than articular process; postmaxillary process narrow and sharp. Dentary with a single series of villiform teeth on upper margin; dorsal arm very wide. Hyomandibular 0.33 time as long as cranium; anterior two zygapophyses distinctly apart from each other. Mesopterygoid large, 1.08 times as long as hyomandibular, and concave on upper surface. Fore part of pterygoid neither wide nor produced into a process. Palatine with a single series of villiform teeth on anterior half of ventral surface. Opercle much shorter than interopercle. Glossohyal narrow, rod-shaped, and with villiform teeth on dorsal surface. Urohyal low, longer than distance from fore end of hypohyal to rear end of epihyal; lateral wings broad and present along whole length of its ventral border. Ceratohyal window ovoidal in shape, located a little in front of the middle of longitudinal groove of ceratohyal. Gill-rakers on first arch $36+11=47$; longest of them 0.61 time as long as diameter of eye, and slightly shorter than the corresponding gill-lamella. Main tubercles on the same $21+5=26$; each of them highly raised to form a ridge. Preorbital bone ovoidal in shape, bulged on surface, with a deep notch on posterior border, and twice as long as wide. First suborbital bone ovoidal in shape; second suborbital small, rod-shaped; third suborbital somewhat wider, irregularly quadrangular in shape; fourth suborbital en-

larged, and next to preorbital bone in size. Suborbital lamina very narrow, and in contact with first suborbital bone. Suborbital process scarcely developed. Posttemporal very low; dorsal arm much longer than ventral one. Clavicle 0.68 time as long as cranium; external and internal shelves at an angle of 45°. Dorsal member of postclavicle wide and flattened; ventral member of the same somewhat enlarged, ovate in its upper part, but much narrowed downward into a form of a rib. Pelvic girdle 2.7 times as long as wide. Postpelvic process only slightly forked at end.

Remarks:

The specimen 243.0 mm long contained numerous flagments of shrimps and fish scales in its alimentary canal.

Decapterus maruadsi (Temminck and Schlegel)

Caranx maruadsi Temminck and Schlegel, Pisces, Siebold's Fauna Japonica, p. 109, pl. 158, fig. 2, 1848-Günther, Cat. Fishes British Mus., vol. 2, p. 428, 1860.

Decapterus maruadsi Bleeker, verh. Bat. Gen., 26, Japan, p. 100, 1857-Wakiya, Ann. Carnegie Mus., vol. 15, pp. 156–157, pl. 17, fig. 2, 1924.

Material examined:

8 specimens, 279.0–196.0 mm long, at Kuki-ura, Mie Prefecture, 8–9 November, 1957.

3 specimens, Nos. 700, S. 44, S. 30 (Collection of Department of Fisheries, Faculty of Agriculture, Kyoto University), 202.0–193.0 mm long, at South China sea, May, 1957, collected by Dr. Hirotoshi Asano.

2 specimens, 260.5–257.0 mm long, at Toba, Mie Prefecture, August, 1958.

External:

Depth 4.26–4.50; head 3.69–3.84; from tip of snout to origin of first dorsal fin 3.07–3.28; from tip of snout to origin of second dorsal fin 1.93–2.05; from tip of snout to origin of ventral fin 3.61–3.70; from tip of snout to origin of anal fin 1.67–1.81; (numeral represents the ratio of standard length to each item). Snout 2.92–3.40; eye 3.86–4.45; interorbital space 3.49–4.50; upper jaw 2.58–3.58; height of first dorsal fin 1.64–1.81; base of the same 1.68–1.87; height of second dorsal fin 2.12–2.34; base of the same 0.62–0.71; height of anal fin 2.37–2.61; base of the same 0.79–0.88; pectoral 0.99–1.12; ventral 1.96–2.08; from anterior side of anus to origin of anal fin 2.55–3.58; length of caudal peduncle 2.98–3.75; depth of the same 6.20–6.51; ventral spine 4.14–5.63; anal spine 4.50–5.80; ratios of head length to each item. ID. VIII; IID. I, 34–30; A. I, 27–30; P. i, 21–19; scutes 35–33.

Body somewhat compressed. Maxillary not reaching fore border of eye; lower jaw slightly longer than upper jaw. Lateral line somewhat strongly arched, straight from thirteenth or fourteenth soft ray of second dorsal fin backward. Scutes relatively large in size, discernible in entire length of the straight portion of lateral line; largest of them 0.78–0.85 time as long as diameter of eye.

Color in formalin dark grayish brown in dorsal area, paler in ventral area; first dorsal fin blackish; second dorsal fin gray, with darker marginal and white marginal zones; caudal and pectoral fins gray; anal and ventral fins white; opercular flap with a prominent black spot in its upper part.

Internal:

Material consists of two specimens, with standard length 279.0–203.0 mm and cranial length 58.5–45.0 mm.

Rostral length 3.22–3.34; diameter of orbit 3.33–3.44; postorbital length 2.54–2.64; depth 2.30–2.37; width 2.25; interorbital width 3.29–3.38; ratios between cranial length and respective items.

Cranium elongate, narrow, forming a narrow isosceles triangle in dorsal aspect. Mesethmoid-vomerine keel low but well-developed. Vomer with a small ovoidal band of villiform teeth on each side of ventral surface of its head portion, and with a low mid-ventral crest marginated by a single row of teeth in shaft. Superior portion of mesethmoid not broad, and scarcely protruding beyond fore ends of frontals. Olfactory cavity wide and deep. Fronto-supraoccipital crest relatively low, 0.18 time as high as cranium. Supraoccipital occupying about half the dorsal edge of median crest, and reaching a little in front of posterior border of orbit. Ventral surface of parasphenoid narrow and flat in the region of orbital floor, but somewhat round in the region of floor of myodome. Posterior perforation of myodome wide. Pterotic window large. Posterior process sharp, and triangular in dorsal aspect. Zygapophyses of exoccipitals not meeting together above basioccipital, which form the floor of foramen magnum. Supramaxillary 0.72 time as long as maxillary. Ascending process of premaxillary 0.47 time as long as the bone; articular process exceeding ascending one in height; postmaxillary process narrow and sharp. Dorsal and ventral arms of dentary making a right angle between each other. Lower margin of premaxillary and upper margin of dentary with a single row of teeth. Hyomandibular 0.41–0.43 time as long as cranium; anterior two zygapophyses distinctly apart from each other. Metapterygoid lamina absent. Mesopterygoid equal to hyomandibular in length. Pterygoid not particularly widened in its fore part and not produced into a process at dorso-anterior corner. Palatine with a narrow band of villiform teeth on lower surface. Glossohyal rod-shaped and armed with a narrow band of villiform teeth occupying posterior two thirds of dorsal surface. Urohyal low, naviculate in lateral aspect, about as long as the distance from fore end of hypohyal to hind end of epihyal, and provided with broadly expanding lateral wings. Ceratohyal ovoidal in shape, situated a little in front of the middle of longitudinal groove of ceratohyal. Gill-rakers on first arch $38+13=51$; longest of them 0.71–0.68 time as long as diameter of eye, and of about the same length as the corresponding gill-lamella. Main tubercles on the same $23+9=32$; each of them a strong bulge. Preorbital bone ovate, 1.7 times as long as wide, bulged on surface, and deeply notched on posterior. First, second and third subor-

bital bones moderately wide. Fourth suborbital much more enlarged, and succeeding to preorbital bone in size. Suborbital lamina narrow, and in contact with first suborital bone. Suborbital process aciculate. Supraclavicle slender, elongate, and provided with a disc-like expansion at about lower one third of its anterior side. Clavicle 0.80–0.77 time as long as cranium; external shelf somewhat wider than internal one, meeting the latter at an acute angle. Dorsal member of postclavicle wide and flat; ventral member of the same somewhat rhomboidal in shape in upper half, but narrowed into a slender rib in lower half. Pelvic girdle thrice as long as wide, and somewhat depressed. Postpelvic process forked at posterior end.

Remarks:

The food taken by the specimen 279.0 mm long, collected at Kuki-ura consists of numerous fragments of shrimps.

Decapterus akaadsi ABE

Decapterus kurroides akaadsi ABE, Records of the Oceanographic Works in Japan, special no. 2, pp. 175–180, 1958-ABE, Figures and Description of the fishes of Japan, vol. 58, pp. 1215–1219, pl. 235, fig. 593, 1958.

Material examined:

5 specimens, 180.0–172.0 mm long, at Owase fish market, Mie Prefecture, 25 March, 1954.

External:

Depth 3.79–4.00; head 3.12–3.33; from tip of snout to origin of first dorsal fin 2.69–2.96; from tip of snout to origin of second dorsal fin 1.95–2.11; from tip of snout to origin of ventral fin 2.90–3.12; from tip of snout to origin of anal fin 1.47–1.61; (numeral represents the ratio of standard length to each item). Snout 3.05–3.28; eye 3.50–3.75; interorbital space 3.50-3.98; upper jaw 2.50–2.92; height of first dorsal fin 1.81–1.93; base of the same 1.87–2.12; height of second dorsal fin 0.75–0.88; base of the same 2.38–2.62; height of anal fin 2.72–2.76; base of the same 1.02–1.17; pectoral 1.01–1.08; ventral 2.06–2.24; from anterior side of anus to origin of anal fin 2.92–3.23; length of caudal peduncle 3.09–3.79; depth of the same 7.50–8.10; ventral spine 4.04–4.58; anal spine 5.25–7.50; ratios of head length to each item. ID. VIII; IID. I, 27–30; A. I, 20–23; P. i, 20–21; scutes 34–36.

Body low, slightly compressed. Maxillary reaching fore border of eye; lower jaw somewhat lower than upper jaw. Lateral line slightly arched, but straight from twelfth soft ray of second dorsal fin backward. Scutes relatively large, present along entire length of the straight portion of lateral line; largest of them 0.67–0.69 time as long as diameter of eye.

Color in formalin as in *D. maruadsi*.

Internal:

Material consists of a single specimen, with standard length 175.0 mm and cranial length 47.0 mm.

Rostral length 3.50; diameter of orbit 2.54; postorbital length 2.85; depth 2.54; width 2.48; interorbital width 5.23; ratios between cranial length to respective items.

This species much resembling D. maruadsi in the general skeletal characters is distinct from the latter in several points to be mentioned below.

Fronto-supraoccipital crest low, 0.16 time as high as cranium at the center of brain case; its dorsal border almost entire, and without any notch in the boundary between frontal and supraoccipital regions. Vomer devoid of teeth in its head portion. Glossohyal narrow, spatulate in shape, and with a narrow band of villiform teeth on posterior half of dorsal surface. Urohyal slightly shorter than distance from fore end of hypohyal to rear end of epihyal. Ceratohyal window large in size and oval in shape; its antero-posterior caliber half the length of ceratohyal. Gill-rakers on first arch 28+10=38; longest of them 0.54 time the diameter of eye. Main tubercles on the same 16+5=21; each of them well raised.

Remarks:

The specimens here dealt with agree well with the original description and figure given by Abe (1958).

When alive, dorsal, pectoral and caudal fins were tinged with red.

Decapterus macrosoma BLEEKER

Decapterus macrosoma Bleeker, Nat. Tijids. Ned., vol. 1, p. 358, 1851-Wakiya, Ann. Carnegie Mus., vol. 15, p. 153, pl. 16, fig. 2, 1924-Barnard, Ann. South African Mus., vol. 21, p. 535, 1925-27-Weber and de Beaufort, Fishes Indo-Australian Archipelago, vol. 6, p. 197, 1931-Norman, Ann. Mag. Nat. Hist., vol. 16, p. 262, 1935.

Caranx macrosoma Günther, Cat. Fishes British Mus., vol. 2, p. 425, 1860.

Decapterus macrosomus Jordan and Evermann, Proc. U. S. Nat. Mus., vol. 25, p. 337, 1903.

Decapterus macarellus macrosoma Nichols, American Mus., Nat. Hist. Novitates, no. 1196, p. 7, 1942.

Material examined:

4 specimens, 284.0–241.0 mm long, at Izu-Ôshima, September, 1955.

External:

Depth 5.16–5.45; head 3.90–4.05; from tip of snout to origin of first dorsal fin 2.78–3.05; from tip of snout to origin of second dorsal fin 1.82–1.90; from tip of snout to origin of ventral fin 3.70–3.77; from tip of snout to origin of anal fin 1.58–1.67; (numeral represents the ratio of standard length to each item). Snout 2.94–3.13; eye 4.43–4.50; interorbital space 3.30–3.72; upper jaw 3.20–3.30; height of first dorsal fin 1.95–2.00; base of the same 1.77–1.84; height of second dorsal fin 2.63–2.83; base of the same 0.69–0.73; height of anal fin 2.97–3.17; base of the same 0.85–0.91; pectoral 1.50–1.52; ventral 2.44; anterior side of anus to origin of caudal peduncle 2.73–3.04; depth of the same 7.8–9.6; ventral spine 4.80–4.92; anal spine 5.67–6.70; ratios of head length to each item. ID. VIII; IID. I, 32–33; A. I,

28–27; P. i, 20–21; scutes 30–26.

Body fusiform, scarcely compressed. Snout much longer than eye; interorbital space slightly wider than eye. Maxillary reaching the midway between posterior nostril and anterior border of eye; lower jaw subequal to upper jaw in length. Lateral line slightly curved, straight from thirteenth soft ray of second dorsal fin backward. Scutes only on posterior half of the straight portion of lateral line; largest scute 0.4 time as long as diameter of eye.

Color in formalin dark bluish brown in dorsal area, paler downward; first and second dorsal fins and caudal fin blackish; anal and paired fins whitish; opercular flap with a prominent black spot in its upper part.

Internal:

Material consists of two specimens, with standard length 284.0–241.0 mm and cranial length 60.5–52.3 mm.

Rostral length 3.27–3.30; diameter of orbit 3.56–3.57; postorbital length 2.50–2.52; depth 2.75; wwidth 2.31–2.33; interorbital width 3.30–3.33; ratios between cranial length and respective items.

Cranium narrow and elongate. Preorbital region of cranium somewhat long and wide. Mesethmoid-vomerine keel conspicuous in the region of vomer, but hardly discernible in the region of mesethmoid. Vomer devoid of teeth; median shaft moderately round on ventral surface, besides with a shallow mid-ventral groove. Superior portion of mesethmoid neither widened nor protruding forward beyond frontals. Olfactory cavity wide and deep. Fronto-supraoccipital crest very low, 0.07 time as high as cranium at the center. Ventral surface of parasphenoid narrow and flat in the region of orbital floor, but moderately rounded in the region of floor of myodome. Posterior opening of myodome somewhat wide, triangular in shape. Pterotic window rather small. Posterior process of pterotic sharp, triangular in shape. Opisthotic produced into a large process, to the base of which lower branch of posttemporal is attached through an intervention of ligament. Zygapophyses of exoccipitals not meeting each other above basioccipital, floor of foramen magnum formed by basioccipital. Supramaxillary 0.73 time as long as maxillary. Outer branch of maxillary fork small in size, about half as wide as posterior region of the bone. Premaxillary devoid of teeth; ascending process low, with height subequal to one third the length of the bone; postmaxillary process narrow, sharp, elongating dorso-posteriorly. Dentary toothless. Hyomandibular 0.36 time as long as cranium; anterior two zygapophyses distinctly apart from each other. Metapterygoid lamina lacking. Mesopterygoid large, about as long as hyomandibular. Fore part of pterygoid neither very wide nor produced into a process. Palatine toothless. Opercle larger than interopercle. Glossohyal long, spatulate in shape, and with a narrow band of villiform teeth on dorsal surface. Urohyal low, naviculate in lateral aspect, and expanded strongly laterally along ventral border; its length subequal to distance from fore end of hypohyal to hind end of epihyal. Cera-

tohyal ovoidal in shape, situated a little in front of the middle of longitudinal groove of ceratohyal. Interhyal small, one fifth as long as glossohyal. Gill-rakers on first arch $39+8=47$; longest of them 0.55 time as long as diameter of eye, and shorter than the corresponding gill-lamella. Main tubercles on the same $20-22+5=25-27$, small in size, and well raised. Preorbital bone ovate, bulged on surface, and provided on posterior border with a somewhat deep notch, into which first suborbital bone is inserted. First suborbital bone elongate oval in shape; second suborbital small, rod-shaped; third suborbital slightly wider; fourth suborbital strongly enlarged into a irregularly quadrangular shaped profile. Suborbital lamina much narrowed, and in contact with first suborbital bone. Suborbital process short but sharp. Dorsal branch of posttemporal much longer than ventral one. Supraclavicle slender, elongated, and provided with a small disc-like expansion at the middle of anterior side. Clavicle 0.70–0.72 time as long as the cranium; external shelf widely expanded, making an acute angle with internal shelf, and covering the latter. Dorsal member of postclavicle wide and lamellar; ventral member of the same enlarged in its upper three fifths, but abruptly narrowed into an aciform in lower part. Pelvic girdle 2.92–2.95 times as long as wide. Postpelvic process not forked on posterior half. Interpelvic keel absent.

Remarks:

The specimen 284.0 mm long contained a number of Euphausia, Copepoda, and fish scales (ctenoid scales) within the alimentary canal.

Decapterus muroadsi (TEMMINCK and SCHLEGEL)

Caranx muroadsi TEMMINCK and SCHLEGEL, Pisces, Fauna Japonica, p. 108, pl. 58, fig. 1, 1844.

Decapterus muroadsi BLEEKER, Verh. Bat. Gen., vol. 26, Ichth. van Japan, p. 101, 1857-JORDAN and EVERMANN, Proc. U. S. Nat. Mus., vol. 25, p. 336, 1903-SNYDER, Proc. U. S. Nat. Mus., vol. 42, p. 4111, 1912-WAKIYA, Ann. Carnegie Mus., vol. 15, pp. 152–153, pl. 16, fig. 1, 1924.

Material examined:

10 specimens, 289.0–203.0 mm long, at Kuki-ura, Mie Prefecture, 8–9 November, 1957.

External:

Depth 4.66–5.10; head 4.13–4.68; from tip of snout to origin of first dorsal fin 3.04–3.10; from tip of snout to origin of second dorsal fin 1.90–1.94; from tip of snout to origin of ventral fin 3.60–3.85; from tip of snout to origin of anal fin 1.90–1.95; (numeral represents the ratio of standard length to each item). Snout 3.09–3.33; eye 4.12–5.00; interorbital space 3.33–3.78; upper jaw 2.80–3.08; height of first dorsal fin 1.87–1.98; base of the same 1.63–1.67; height of second dorsal fin 2.37–2.59; base of the same 0.63–0.67; height of anal fin 2.71–2.90; base of the same 0.78–0.81; pectoral 1.02–1.13; ventral 2.50–2.78; from anterior side of anus to origin of anal fin 2.80–3.04; length of caudal peduncle 2.50–2.69; depth of the same 6.90–7.54; ventral spine 4.83–5.32; anal spine 5.38–6.20; ratios of head length

to each item. ID. VIII; IID. I, 30–33; A. I, 24–27; P. i, 19–21; scutes 30–34.

Body fusiform, scarcely compressed. Snout pointed, longer than diameter of eye. Maxillary hardly reaching fore border of eye; lower jaw slightly protruding beyond upper jaw. Lateral line only slightly curved, straight from twelfth soft ray of second dorsal fin backward. Scutes present only on posterior two thirds of the straight portion of lateral line; largest of them half as long as diameter of eye.

Color in formalin dark bluish brown in dorsal area, becoming paler downward; first dorsal fin brownish; second dorsal fin gray, margined by dark zone; caudal fin gray; anal and paired fins white; opercular flap with a distinct black spot in its upper part.

Internal:

Material consists of two specimens, with standard length 289.0–275.0 mm and cranial length 59.5–56.9 mm.

Rostral length 3.48–3.50; diameter of orbit 3.28–3.30; postorbital length 2.59; depth 2.59; width 2.15–2.16; interorbital width 3.19; ratios between cranial length and respective items.

This species is nearest to *D. macrosoma* in the general skeletal features, but is distinct from the latter in the following points. Mesethmoid-vomerine keel low, but discernible throughout its entire length. Fronto-supraoccipital crest low, half as high as cranium at the center. Myodome with wide triangular posterior foramen. Pterotic window large in size, and more or less cricular in contour. Dentary with a single row of teeth on upper margin. Gill-rakers on first arch 12+39=51; Main tubercles on the same 7+24=31. Postpelvic process relatively short, and widely forked at posterior end.

Megalaspinae, new subfamily

Body fusiform, somewhat compressed. Several finlets present behind second dorsal and anal fins. Scutes large and stout, present on lateral line in its entire length. Preorbital region of cranium very short. Olfactory cavity obliterated. Superior portion of mesethmoid widened from side to side, slightly projecting forward beyond frontals. Fronto-supraoccipital crest very low. Myodome with narrow posterior foramen. Zygapophyses of exoccipitals apart from each other. Premaxillary protrusible. Postmaxillary process much reduced in size, and rounded on upper margin. Pterygoid somewhat widened in fore part. Branchiostegal rays 7 in number. Suborbital lamina very small, and in contact with first and second suborbital bones. Suborbital process long, ensiform and compressed on a plane vertical to suborbital lamina. Interpelvic keel feeble in development. Caudal vertebrae 14 in number. Last two pairs of parapophyses combined by bony bridges. Inferior vertebral feramina present in last four parapophyses and first haemal spine. Imperfect interneural spine 3 in number; first of them in front of first neural spine and

the succeeding two interposed each between every two of the first three neural spines. Both first haemal spine and first interhaemal spine large and stout, firmly united together.

Remarks:

The new subfamily bears a close resemblance to Caranginae, but is different in having the scutes which are astonishingly stout, acuminating upward as well as downward, have sharp, posteriorly directing spines, but lack aperture of sensory canal.

Genus *Megalspis* BLEEKER

Body fusiform, slightly compressed. 10 finlets behind second dorsal, and 6–7 finlets behind fin. Scutes large, stout, discernible on entire length of lateral line. Preorbital region of cranium wide and short. Olfactory cavity absent. Superior portion of mesethmoid widened from side to side and slightly projecting forward frontals. Fronto-supraoccipital crest very low. Posterior opening of myodome very narrow. Zygapophyses of exoccipitals separated from each other beneath foramen magnum. Ascending process of premaxillary short, twice as long as articular process; postmaxillary process small, and rounded on upper margin. Interosseous space between dorsal arm of dentary and articular very narrow. Pterygoid not particularly wide in its fore part, and not produced anteriorly into a process. Preorbital bone narrow, and flattened on surface. Suborbital lamina very small, and in contact with first and second suborbital bones. Suborbital process long, ensiform, and compressed on a plane vertical to suborbital lamina. External and internal shelves making a right angle between each other. Ventral member of postclavicle flat and lamellar in its upper one third, but rib-shaped in its lower two thirds. Interpelvic keel developed. Last two pairs of parapophyses combined by bony bribges. Inferior vertebral foramina present in last four parapophyses and in first haemal spine.

Megalaspis cordyla (LINNÉ)

Scomber cordyla LINNÉ, Syst. Nat., ed. 10, p. 298, 1758.

Scomber rottleli RÜPPELL, Atlas Reise Nordl. Afrika, Fische Rothen Meeres p. 102, 1833-CUVIER and VALENCIENNES, Hist. Nat. Poissons, vol. 9, p. 29, 1833-GÜNTHER, Cat. Fishes British Mus., vol. 2, p. 424, 1860-DAY, Fishes India, p. 213, 1878.

Scomber rottleri BLOCH, Naturges. Ausland, Fische, vol. 7, p. 88, pl. 346, 1873.

Trachurus rottleri BLEEKER, Nat. Geneesk. Arch. Ned. Ind., vol. 2, p. 517, 1845.

Megalaspis rottleri BLEEKER, Nat. Tijids. Ned. Ind. vol. 2, p. 213, 1851.

Megalaspis cordyla JORDAN and EVERMANN, Proc. U. S. Nat. Mus., vol. 25, p. 336, 1902-EVERMANN and SEALE, Bull. U. S. Bur. Fisheries, vol. 26, p. 65, 1907-WAKIYA, Ann. Carnegie Mus., vol. 15, p. 147, pl. 15, fig. 1, 1924-OSHIMA, Philippine Jour. Sci., vol. 26, p. 364, 1925-FOWLER, Proc. Phila. Acad. Sci., vol. 79, p. 268, 1927-WEBER and DE BEAUFORT, Fishes Indo-Australian Archipelago, vol. 6, p. 193, fig. 40, 1931.

Material examined:

1 specimen, 246.0 mm long, at Kumano-nada, 21 September, 1955.

3 specimens, Nos. S. 697, S. 696, S. 188, S. 155 (Collection of Department of Fisheries, Faculty of Agriculture, Kyoto University), 310.0–242.0 mm long, at Tongking Bay, June, 1957, collected by Dr. Hirotoshi Asano.

External:

Depth 3.78–4.17; head 3.88–4.48; from tip of snout to origin of first dorsal fin 3.15–3.14; from tip of snout to origin of second dorsal fin 2.12–2.30; from tip of snout to origin of ventral fin 3.56–4.43; from tip snout to origin of anal fin 1.79–1.91; (numeral represents the ratio of standard length to each item). Snout 3.78–4.50; eye 3.65–4.54; interorbital space 3.09–3.37; height of first dorsal fin 2.39–2.66; base of the same 1.69–1.96; height of second dorsal fin 1.83–1.92; base of the same 0.49–0.54; height of anal fin 1.88–2.32; base of the same 0.63–0.67; pectoral 0.62–0.83; ventral 1.74–1.89; from anterior side of anus to origin of anal fin 1.71–2.04; length of caudal (measured from base of caudal fin to last finlet of anal fin) 3.00–4.50; depth of the same 9.12–9.85; ventral spine 3.78–4.52; anal spine 3.68–4.52; ratios of head length to each item. ID. VII-VIII; IID. I, 10; finlets behind second dorsal fin 10; A. I, 9–10; finlets behind anal fin 6–7; P. i, 19–20, scutes 48–58.

Body fusiform. Snout pointed, equal to eye in length; maxillary extending to center of eye; lower jaw somewhat longer than upper jaw. Anterior and posterior adipose eyelids slightly covering marginal part of pupil. Lateral line strongly arched, and straight from the middle of pectoral fin backwards. Scutes very large, present on lateral line in the entire length.

Color in formalin dark brown above, paler below; fins brownish, except for anal fin, which is paler; upper margin of second dorsal fin and posterior margin of caudal fin blackish; opercular flap with a prominent black spot in its upper part.

Fig. 61. *Megalaspis cordyla* (Linné), 310.0 mm in standard length.

Internal:

Material consists of a single specimen, with standard length 246.0 mm and cranial length 47.0 mm.

Rostral length 5.22; diameter of orbit 2.88; postorbital length 2.00; depth 2.09; width 2.04; interorbital width 3.03; ratios between cranial length and respective

items.

Preorbital region of cranium relatively low, about as high as wide. Dorsal border evenly and gracefully descending from medio-dorsal ridge of frontal to preeorbital. Mesethmoid-vomerine keel describing a round curve. Vomer toothed; median shaft flattened on ventral surface. Superior portion of mesethmoid widened from side to side, and slightly protruding beyond frontals. Olfactory cavity almost obliterated. Orbital wing of ectethmoid strongly expanding, and assuming an appearance of an arm in dorsal aspect. Ventral surface of parasphenoid narrow and flattened in the region of orbital floor, but obtusely ridged in the region of floor of myodome. Fronto-suproccipital crest very low, one ninth as high as cranium. Pterotic produced backward into a thin, ensiform spine. Opisthotic produced backward into a subtriangular spine, with which lower limb of posttemporal is united. Zygapophyses of exoccipitals widely apart; floor of foramen magnum formed by basioccipital. Posterior opening of myodome very narrow, slit-like. Supramaxillary relatively large in size, about half as long as maxillary. Premaxillary with a narrow band of villiform teeth on lower margin besides with an outer row of stouter canine teeth; ascending process short, 0.3 tim as long as premaxillary; articular process shorter than ascending process; postmaxillary process much reduced in size. Dentary with a single row of teeth on upper margin. Anterior two zygapophyses of the head of hyomandibular distinctly apart from each other. Metapterygoid lamina obsolete. Mesopterygoid large, ovate in outline, and 1.3 times as long as hyomandibular. Pterygoid ordinary in width in its fore part, and not produced into a process. Principal region of palatine as well as fore region of pterygoid bent outward, thus lying on a plane perpendicular to the body side. Palatine with a small band of villiform teeth on lower, inner surface. Opercle subequal to interopercle in length. Glossohyal spatulate, and with a narrow longitudinal band of villiform teetth on dorsal surface. Urohyal somewhat elongate, larger in length than the distance from fore end of ceratohyal to rear end of epihyal, but shorter than hyoid body; lateral wings moderately expanding. Ceratohyal window slit-like. Gill-rakers on first arch very short, $19+8=27$; longest of them 0.6 time as long as the corresponding gill-lamella. Main tubercles on the same $15+5=20$; each of them well raised, and beset with prickles more or less equal in size. Preorbital bone narrow, flat, twice as long as wide, and scarcely notched on posterior border. Third and fourth suborbital bones much enlarged in size. Suborbital lamina 0.75 time as long as wide, and in contact with first and second suborbital bones. Suborbital process ensiform, compressed on a plane vertical to suborbital lamina. External and internal shelves of clavicle making a right angle, and, when viewed from side, a large posterior marginal area of internal one exposed. Dorsal member of postclavicle lamellar and reniform; ventral member of the same triangular in its upper part but elongate into a rib in its lower part. Pelvic girdle 2.82 times as long as wide. Postpelvic process long, and widely forked at posterior end. Interpelvic keel feebly developed.

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On the Male of *Pseudocaligus fugu* YAMAGUTI (Copepoda: Caligoida)

Sueo M. SHIINO

(With One Text-figure)

Pseudocaligus fugu YAMAGUTI is a parasitic copepod occurring on the body surface of globefishes in Japanese waters, and has been known only from the female. Two lots of specimens obtained from *Spheroides niphobles* JORDAN et SNYDER were recently forwarded to me for identification, one by Mr. R. OKAMOTO of the Inland Fisheries Research Institute in Hiroshima, and the other by Mr. N. YAMAGUCHI of Mie Prefectural Fisheries Experimental Station at Hamajima. Since these lots contained a number of specimens of both sexes, I could have an opportunity of studying the male form.

Pseudocaligus fugu YAMAGUTI

(Fig. 1)

YAMAGUTI 1936: 9-10, Pl. 5, Figs. 86 89, Pl. 7, Figs. 96-99; SHIINO 1959: 342-343.

Materials: No. 588. 26 females and 20 males taken from *Spheroides niphobles* JORDAN et SNYDER kept in the aquarium of the Inland Fisheries Research Institute in Hiroshima, by R. OKAMOTO, September 1963. The females are colorless in alcohol, but their carapace is scattered all over the surface by brownish pigment spots, which are deeper in color around the eye than in other areas, and may have been black when alive. Eye pigment is darker. Genital segment and egg strings are white. Pigment spots are larger and of deeper color in the male than in the female. The largest female 3.61 mm × 1.85 mm, with egg tube 3.23 mm long; the smallest female 3.08 mm × 1.58 mm, with egg tube 1.58 mm long. The largest male 3.31 mm × 2.00 mm; the smallest male 2.27 mm × 1.69 mm. No. 589. 14 females and 19 males collected on the same host species at Hamajima, Ago Bay, by a schoolboy, July 22, 1963, and presented through the courtesy of N. YAMAGUCHI. The females are whitish in color in formalin, almost without pigment spots except for those around the eye, or spotted with very light pigment all over the carapace. The males are covered with larger spots of deeper color which are distributed uniformly on entire surface.

A male from the former lot is made the allotype.

Male: The carapace is wider posteriorly than anteriorly and widely rounded

on the sides. The hinder border forms a trapezoid with well rounded lateral angles and extending beyond the lateral lobes. The paired dorsal ribs are parallel in their anterior halves, whereas divergent in their posterior halves. The eyes are located a little in front of the centre of the medio-anterior region of the carapace. The fourth segment is small, a little narrower than the carapace, half as long as its

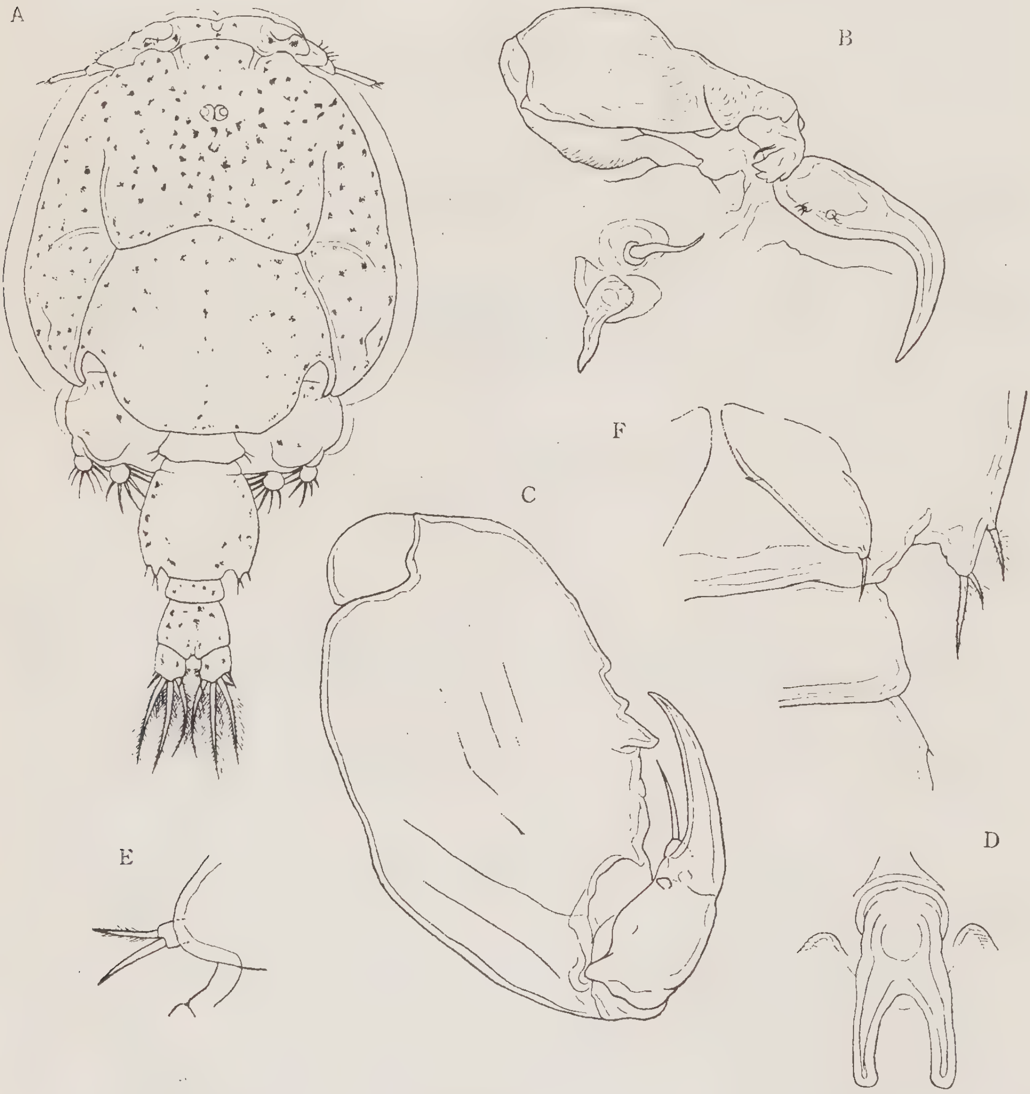

Fig. 1. *Pseudocaligus fugu* YAMAGUTI, male.
A, dorsal view; B, second antenna and first and second maxillae; C, second maxilliped; D, sternal furca; E, fourth leg, dorsal view; F, caudo-lateral angle of genital segment, showing fifth and sixth leg rudiments, ventral view. A ×18; B–F ×80.

own width, and cuneiform on the sides. The genital segment is two sevenths as long as the carapace, as wide as its own length, and has slightly swollen lateral borders. It is produced at each caudo-lateral angle into a small conical process, terminating in two unequal setose spines, which are associated a little in front of their bases with another spine. A pair of low broad ridges, diverging backward and ending in a short simple spine, are present on the ventral surface of the segment near its hind margin. These processes and ridges may represent the remnants of the fifth and sixth pairs of legs. The abdomen is short, two thirds as long as and same time as wide as the preceding segment. It is composed of two segments. The first segment occupies a quarter of the entire length of the abdomen, and is narrower than the second and transversely linear. The second segment is slightly widening caudally and ends in a V-shape. The caudal rami are short, squarish, and armed with spines stouter than in the female.

The terminal segment of the first antennae is relatively longer than in the female. The second antennae, the two pairs of maxillae and the second maxillipeds are different in constitution from those of that sex. The second antennae have the short terminal segment curved at the apex, which is divided into a number of triangular claws and provided just behind with a tiny hair; the second segment has a low boss near its end; this and the first segment bear striations on their surface. The first maxillae are stout, sharp and strongly curved like a hook. Each of the second maxillae is a short spiniform process, and associated just in front of the base with a relatively long, thick hair. The second maxillipeds are powerful and much stouter than in other sex. The palm is greatly swollen and furnished on the inner border near the end with a prominent conical process, which is accompanied just proximally with feebler accessory ones. The terminal claw is thick in the basal part, sharply pointed at the apex, which reaches beyond that process of the palm, and carries an elongate spine at about the middle of its length. The sternal furca has both branches only slightly diverging and ending in blunt tips. The fourth leg rudiments and other appendages are as in the female in structure.

Remarks: The male of the present species is distinguishable from the males of *Pseudocaligus brevipedes* (BASSETT-SMITH), *Ps. apodus* BRIAN and *Ps. laminatus* RANGNEKAR by the shape of the genital segment as well as by the two-segmented abdomen, and from that of *Ps. fistulariae* PILLAI by that the fourth leg rudiments are much smaller and one-segmented. *Caligus fugu* YAMAGUTI and YAMASU was recorded from the mouth cavity of globefishes inclusive of *Spheroides niphobles*. This parasite, however, is entirely different from the present one in having the well-developed fourth legs, though their males resemble each oher in the constitution of the genital segment and abdomen.

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Parasitic Copepods of the Eastern Pacific Fishes

1. Records of the Known Species

Sueo M. Shiino

(With Four Text-figures)

In two of my previous papers (1959b, 1960a), I described a number of species of the parasitic copepods obtained from the fishes in the Eastern Pacific by Dr. W. L. Klawe of the Inter-American Tropical Tuna Commission. After the publication of these works, I received further lots of specimens of this group which he very kindly sent to me from time to time. These specimens collected by him in the Pacific Ocean off the coast of California, of Central and South America and in the Sea around Hawaii have come to a vast number. Besides these, there are in my hand several lots which were collected by Dr. James Joseph of that Commission in some of these regions and sent to me for identification. All of these lots will be dealt with in a series of papers, which I hope to appear hereafter without obstruction. As a start of this series, the present article is devoted to the records of the known species.

Caligus productus Dana

Dana 1852, pp. 1354-1355, Pl. 94, Fig. 4; Shiino 1959a, pp. 14-20, Figs. 6-8; 1959b, pp. 297-300, Fig. 13. As for synonyms refer to Shiino 1959a

Material No. 557. Locality: The Pacific, approx. 0°12′N, 80°27′W. Date: April 20, 1962. Collector: W. L. Klawe. Host: *Katsuwonus* sp. caught by night light. On the external surface.

Two females with egg strings and one male. Both the females were parasitized by a hyperparasitic trematode which is attached to the end of the genital segment. Coloration: The body of both sexes transparent, whitish in formalin, and the females yellowish white in the genital segment. No appreciable pigment spots. Egg strings also yellowish white. Measurements: Female 1. Entire length 4.74 mm, carapace 2.12 mm × 1.87 mm, fourth segment 0.37 mm × 0.50 mm, genital segment 1.08 mm long on the midline, 1.46 mm long including lateral lobes, 1.04 mm wide, abdomen 1.17 mm × 0.37 mm, first segment of the same 0.62 mm long, second segment of the same 0.55 mm long, egg string 1.69 mm long. Female 2. Entire length 5.39 mm, carapace 2.38 mm × 2.04 mm, fourth segment 0.42 mm × 0.58 mm, genital segment 1.17 mm long on the midline, 1.67 mm long including

lateral lobes, 1.17 mm wide, abdomen 1.42 mm × 0.42 mm, first segment of the same 0.58 mm long, second segment of the same 0.84 mm long, egg string 3.31 mm long. Male: Entire length 4.59 mm, carapace 2.38 mm × 1.96 mm, fourth segment 0.21 mm × 0.58 mm, genital segment 1.12 mm × 0.71 mm, abdomen 0.58 mm long, first segment of the same 0.30 mm × 0.37 mm, second segment of the same 0.58 mm × 0.33 mm.

The females possess the genital segment similar in constitution to that shown in Fig. 8A, Shiino 1959a, and have the lateral lobes somewhat turned inward. The abdomen is indistinctly two-segmented. The genital segment of the male is in agreement with that represented in Fig. 8D, Shiino 1959a in structure, and the abdomen shows more or less distinct segmentation.

Caligus bonito Wilson

Wilson 1905, pp. 589-594, Pl. 13, Figs. 150-153; Shiino 1960a, pp. 527-528, Fig. 1. As for bibliography refer to Shiino 1960a.

Material No. 573. Locality: The Pacific, 22°26′N, 112°25′W. Date: June 24, 1963. Collector: J. Joseph. Host: *Katsuwonus pelamis* 650 mm long. On the gills.

A single female without egg strings. Coloration: The body is colorless except in the genital segment which is white. Measurements: 5.39 mm × 2.31 mm.

Material No. 574. Locality: The Pacific, at the same spot as before. Date: On the same date. Collector: J. Joseph. Host: *Katsuwonus pelamis* 600 mm long. On the gills.

Two females and two detached egg strings. Coloration: Same as material No. 573, egg string whitish. Measurements: 6.08 mm × 2.46 mm; 6.15 mm × 2.54 mm. Egg strings 4.08 mm and 4.00 mm long.

Material No. 575. Locality: The Pacific, 2 miles off Cabo San Lucas, Baja California, Mexico. Date: May 28, 1962. Collector: J. Joseph. Host: *Euthynnus lineatus*. External, ca. 1/2 inch above the vent.

A single female before the first oviposition. Coloration: colorless, without pigment. Measurements: 4.00 mm × 1.54 mm.

Caligus coryphaenae Steenstrup et Lütken
(Fig. 1)

Steenstrup and Lütken, 1861, pp. 360-362, Pl. 4, Fig. 7; Shiino 1959a, pp. 2-8, Figs. 1-2; 1959b, pp. 294-297, Fig. 12. As for bibliography refer to Shiino 1959a.

Material No. 562. Locality: Hawaiian waters; obtained at Honolulu Fish Market. Date: September 12, 1961. Collector: Douglas C. Vann m/v Gilden Glow. Host: *Coryphaena hippurus*. External.

Five females with egg strings, one adult female without egg string, one male, and one incomplete specimen represented only by the carapace. Coloration: Both

the sexes light yellowish brown in formalin, egg strings lighter in color. Measurements of females: 7.24 mm × 2.31 mm, egg string 7.08 mm long; 7.16 mm × 2.69 mm, egg string 8.48 mm long; 7.09 mm × 2.62 mm, egg string 7.70 mm long; 6.48 mm × 2.69 mm, egg string 6.54 mm long; 6.15 mm × 2.31 mm, egg string 5.39 mm long; 6.46 mm × 2.38 mm. Measurements of male: 4.77 mm × 2.31 mm.

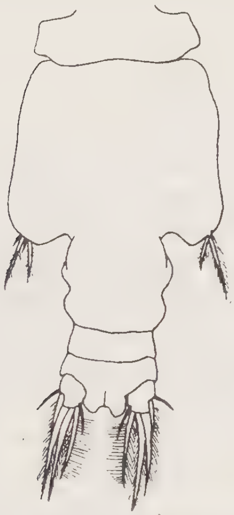

Fig. 1. *Caligus coryphaenae* STEENSTRUP et LÜTKEN, young female × 21.

Material No. 558. Locality: Ecuador; Cape San Francisco bears 36°T., −17 miles. Date: April 24, 1962. Collector: W. L. KLAWE. Host: *Coryphaena hippurus* caught by night light. External.

Two adult females with egg strings, two somewhat younger females and two adult males. Coloration: Yellowish in formalin. Measurements of adult females: 6.47 mm × 2.54 mm, egg string 8.70 mm long; 6.23 mm × 2.38 mm, egg string 3.16 mm long. Measurements of younger females: 5.69 mm × 2.54 mm; 5.08 mm × 2.38 mm. Measurements of males: 5.08 mm × 2.46 mm; 4.46 mm × 2.31 mm.

In the younger females the posterior region of body (Fig. 1) is relatively shorter than in the fully adult females, as this will be seen from the comparison of them with respect to the proportions of various regions of body (Table 1).

Table 1. Proportions of body regions as represented by 26 times the real values.

	Carapace	4th segment	Genital segment (excl. lateral lobes)	Abdomen
Young female 1	75 × 61	8 × 24	25 × 30	25 × 15
Young female 2	80 × 66	9 × 26	29 × 36	31 × 19
Adult female	80 × 68	8 × 27	39 × 43	43 × 21

The paired posterior lobes of the genital segment are not so well developed as in the adult, and the abdomen is relatively shorter as compared with its width.

Lepeophtheirus crassus (**WILSON et BERE**)

(Fig. 2)

Gloiopotes crassus, BERE 1936, pp. 590–593, Pl. 5, Figs. 104–111, Pl. 6, Figs. 125–155. *Lepeophtheirus crassus*, SHIINO 1960b, pp. 546–552, Figs. 3–4. As for synonymy refer to SHIINO 1960b.

Material No. 570. Locality: The Pacific, 16°25.0′S, 96°58.3′W. Station No. 16 (fishing) in her twelfth cruise of "Shoyo Maru", the survey ship of the Ministry of Agriculture and Forestry of Japanese Government. Date: January 13, 1963.

Collector: W. L. KLAWE. Host: Remora from the Striped Marlin. External surface.

Two females with egg strings. Coloration: Body pale yellowish white, genital segment opaque and white, egg strings yellow. Measurements: 6.55 mm × 3.46 mm, egg string 5.00 mm long, 6.77 mm × 3.69 mm, egg string 6.07 mm long.

Material No. 569. Locality: The Pacific, 19°34.3′S, 92°45.4′W. Station No. 15 (fishing) in her twelfth cruise of "Shoyo Maru". Date: January 11, 1963. Collector: W. L. KLAWE. Host: Remora from *Makaira audex.* External surface.

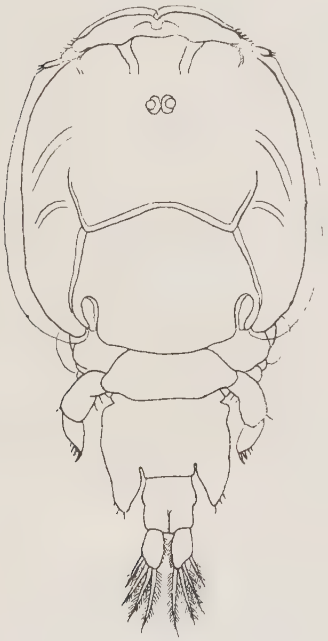

Fig. 2. *Lepeophtheirus crassus* (WILSON et BERE), young female. ×21.

Six females, each with egg strings, and one male. In two of the females the egg strings were mutilated at their apices. Coloration: Same as in material No. 570. Measurements of females: 7.54 mm × 3.92 mm, egg string 6.15 mm long: 6.85 mm × 3.69 mm, egg string 6.93 mm long; 6.77 mm × 3.61 mm; 6.62 mm × 3.62 mm, egg string 5.61 mm long; 6.23 mm × 3.38 mm; 6.00 mm × 3.61 mm, egg string 1.15 mm long. Measurements of male: 5.00 mm × 2.84 mm.

Material No. 549. Locality: The Pacific, 8°14′N, 84°17′W. Date: April 27, 1962. Collector: W. L. KLAWE. Host: *Remilegia australis* on *Delphinus bairdi.* On the skin of *Remilegia.*

Eleven females carrying egg strings, two males and one young female. One of the males was clasping the abdomen of the young female. Coloration: Body whitish in formalin, but with the central region of carapace and the oviduct pale yellowish. No pigment except that of eye. Measurements of females: 7.46 mm × 3.46 mm; 7.15 mm × 3.38 mm, egg string 3.85 mm long; 6.93 mm × 3.23 mm, egg string 4.70 mm long; 6.70 mm × 3.61 mm, egg string 3.85 mm long; 6.44 mm × 3.53 mm; 6.44 mm × 3.39 mm; 6.39 mm × 3.23 mm, egg string 4.70 mm long; 6.38 mm × 3.23 mm, egg string 3.31 mm long; 6.23 mm × 3.54 mm, egg string 2.92 mm long; 6.23 mm × 3.38 mm, egg string 4.16 mm long; 6.15 mm × 3.08 mm. Measurements of males: 3.77 mm × 2.16 mm; 4.62 mm × 2.46 mm (the male seizing the young female). Measurements of young female: 3.46 mm × 2.40 mm.

In the act of copulation, the male rides on the back of the young female suspending its body backward from the posterior segments of the latter. The former clasps the latter by the anterior end of the genital segment with the second antennae and by the abdomen with the second maxillipeds.

The young female differs from the adult in that the caudo-lateral lobes of the

genital segment are triangular in shape and not oval as in the adult, and in that the abdomen is short and composed of a single segment instead of two. The fourth legs are not attaining their full growth.

Lepeophtheirus parvus WILSON
(Figs. 3-4)

WILSON 1908, pp. 441-443, Pl. 68; SHIINO 1959b, pp. 310-315, Figs. 17-18.

Material No. 568. Locality: San Diego, California. Date: December 28, 1960. Collector: W. L. KLAWE. Host: *Pimelometopon pulchrum.* External.

Nine adult females, two juvenile females different between each other in their developmental stages, six males and a very small couple embracing each other. Coloration: Body pale yellowish, egg strings similar in color. Measurements of females: 5.92 mm × 3.23 mm, egg string 3.31 mm long; 5.85 mm × 3.38 mm, egg string 3.16 mm long; 5.69 mm × 3.38 mm, egg string 3.16 mm long; 5.69 mm × 3.23 mm; 5.61 mm × 3.15 mm, egg string 2.69 mm long; 5.61 mm × 3.23 mm, egg string 3.69 mm long; 5.54 mm × 2.92 mm, egg string 3.46 mm long; 5.54 mm × 3.08 mm, egg string 3.38 mm long; 5.46 mm × 3.23 mm. Measurements of males: 3.46 mm × 2.08 mm; 3.46 mm × 2.08 mm; 3.46 mm × 2.08 mm; 3.38 mm × 1.93 mm; 3.23 mm × 1.85 mm; 3.16 mm × 1.77 mm. Measurements of juvenile females: 5.08 mm × 3.08 mm; 3.85 mm × 2.31 mm. Measurements of young couple: female 2.31 mm × 1.62 mm, male 1.46 mm × 0.93 mm.

This species has been described before by myself with respct to the characters of the young female and male. Since the present collection includes a number of adults of both sexes, a supplementary description will be given on the basis of the new materials.

Female: Entire length 5.54 mm, carapace 3.32 mm × 2.92 mm, fourth segment 0.44 mm × 0.98 mm, genital segment 1.11 mm long on the midline, 1.36 mm long including lateral lobes, 1.46 mm wide, abdomen 0.67 mm × 0.44 mm, egg string 3.46 mm long.

The carapace is only slightly longer than wide, wider posteriorly than anteriorly, and gracefully curved on both the anterior and the lateral margins. The frontal plate is half as wide as the carapace and has a narrow marginal rim. The lateral lobes are narrow, not extending beyond the medio-posterior border, which is gracefully arched. The margins of the lobes are fringed by a series of short hairs along their entire lengths besides bearing a relatively broad membraneous flange. The transverse bar of the H-shaped dorsal rib traverses the carapace about its middle and is arched forward. The longitudinal ribs are slightly diverging away from each other both in front and in the rear of the transverse rib. The eyes are located close to the fore margin of the carapace. The lateral sinuses are small and open backward. The fourth segment is small, about one third as wide as the carapace, twice as wide as its own length, and has the sides much narrowed. The

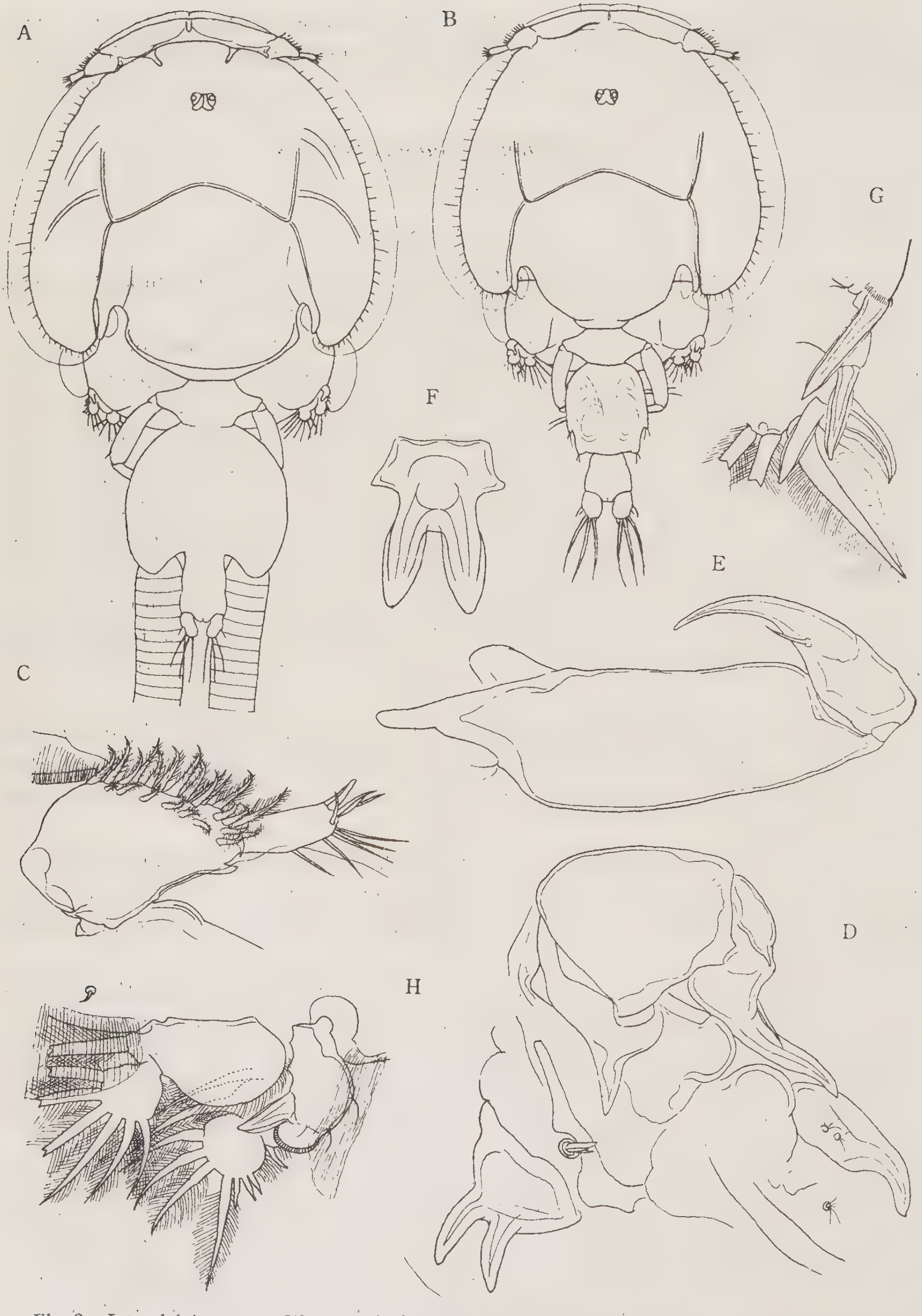

Fig. 3. *Lepeophtheirus parvus* Wilson. A, female; B, male; C-H, female; C, first antenna; D, second antenna, first and second maxillae; E, second maxilliped; F, sternal furca; G, outer border of exopodite of second leg; H, two rami of third leg. A ×16; B ×21; C-H ×93.

genital segment is one third as long as the carapace and a little wider than long. It is cordiform having well curved sides, and is produced backward into a pair of short blunt, triangular, lateral lobes. The abdomen is about half as long as the preceding segment, narrow and one-segmented, though the undulation of the sides suggests the coalescence of two segments.

The first antennae are similar in appearance to those of the young males (cf. Fig. 17, Shiino 1959a). The second antennae bear a sharp posterior process on the basal segment; the middle segment is broad, and the distal segment is simply acuminating to the tip without forming a hook, and carries a minute proximal as well as a longer distal hairs. The first maxillae are only slightly curved, and end in a more or less blunt apex. The second maxillae are forked into two branches which are turned outward. The second maxillipeds are powerful chelae composed of an elongate, relatively slender palm and a well curved claw, which narrows from the broad base rapidly to the sharp apex. The claw reaches the middle of the palm and carries a short hair on the posterior side. The sternal furca has two divergent branches; each of these is shaped like an arrowhead with bluntly pointed apex.

The first thoracic legs are the same as the corresponding legs of the male in structure. The outer spine on the first exopodite segment of the second legs is doubly edged by a narrow rim and provided at the base with a transverse row of fine spinules. The outer spines on the second and third segments bear similar rims which are especially broad in the basal spine of the latter segment. The basal hook of the exopodite of the third legs is expanded outside the terminal claw into a semicircular lobe circumscribed by a narrow striated rim, and carries two tiny hairs on the outer border and another hair on the basal line of that lobe. The fourth legs are elongated and four-segmented. The first segment bears a short subterminal plumose spine on the outer side, the second ends in a short rudimentary unguiform spine, and the third carries a well-developed spine. The last segment is armed at the end with three spines of graded lengths; the innermost of these is the longest, and the outermost is the shortest and about as long as the spine of the previous segment. All the spines are finely pectinate along their borders, or with pectinate rims, and bear each a similarly pectinate basal lamina. The terminal two segments show pectination also on the outer border. The genital segment is provided with a narrow transverse lamella on the caudal margin ventrally to the egg tubes. The sixth legs are a pair of round lobes fringed by three plumose spines which are present on the ventral surface of the segment, one on either side of that lamella. The fifth legs are represented each by a tiny plumose spine located further laterally to the sixth legs.

Male: Entire length 3.46 mm, carapace 2.27 mm × 2.08 mm, fourth segment 0.27 mm × 0.41 mm, genital segment 0.60 mm × 0.58 mm, abdomen 0.32 mm × 0.32 mm. General body constitution is similar to that of the pre-adult male described before (Shiino 1959a, Fig. 17).

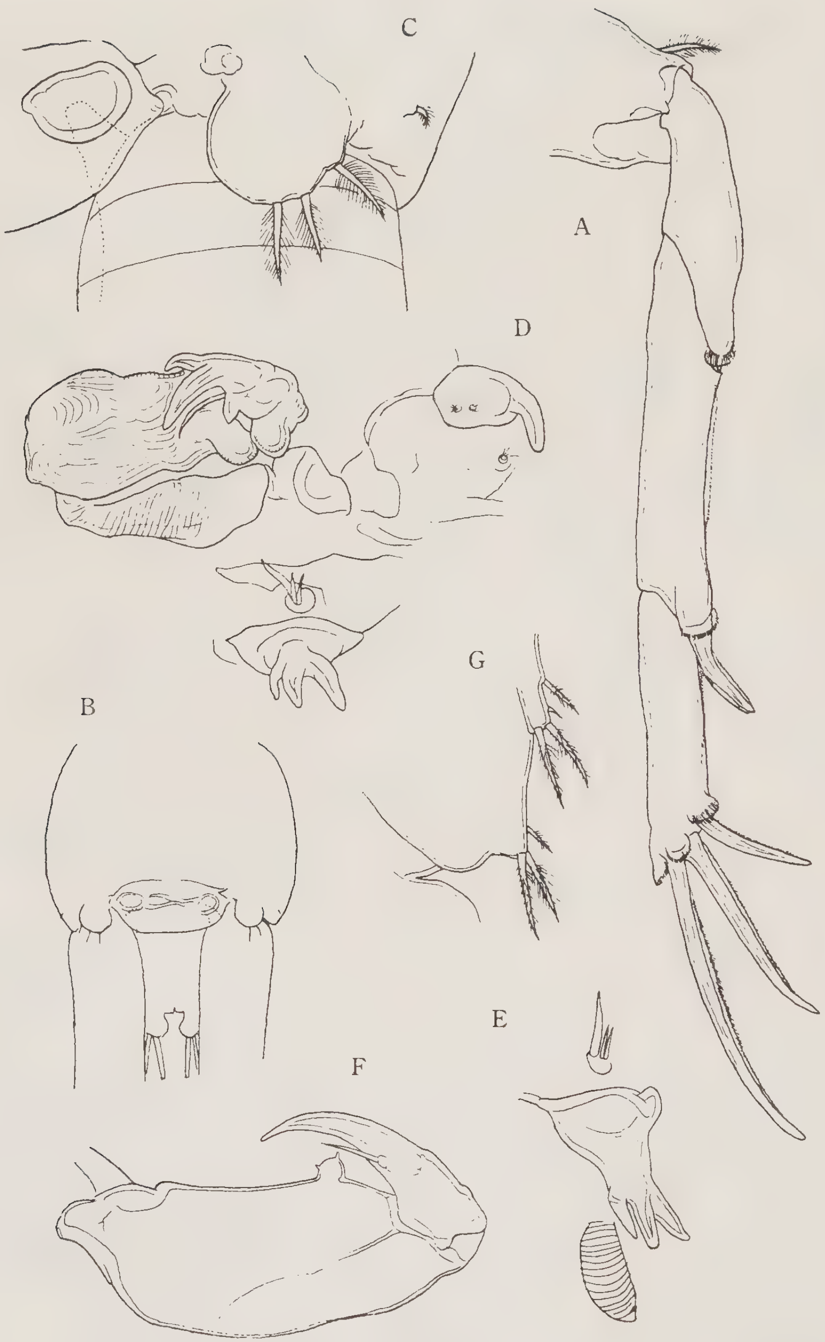

Fig. 4. *Lepeophtheirus parvus* Wilson. A–C, female; A, fourth leg; B, genital segment, ventral side; C, same, postero-lateral angle, further enlarged; D–G, male; D, second antenna, first and second maxillae; E, second maxilla; F, second maxilliped; G, postero-lateral angle of genital segment. A, C ×93; B ×21; D–G ×105.

The second antennae are somewhat different from those of the young males in structure. The first and second segments are covered with more or less parallel surface rugae; the latter segment has an oval terminal bulge on the posterior side. The third segment ends in a sharp claw which is reinforced by two accessory basal claws present one on each side. The segment is swollen at the base into an oval prominent bulge, which comes in contact with that bulge of the penultimate segment, and carries a hair inside the apical claw. The second maxillae are tripartite at the apex; the outer and inner branches are acuminating, while the middle one ends in a blunt tip. The sternal surface bears an elongate oval, corrugated boss on either side of the midventral line in the region just behind the second maxillae. The second maxillipeds are armed with an oval protuberance bearing a few tiny spinules on the inner edge of the palm a short distance behind the base of the terminal claw. The rudiments of the fifth and sixth pairs of legs are as in the juvenile forms.

Midias lobodes WILSON

WILSON 1911, pp. 626-628, Pl. 65; SHIINO 1958, pp. 98-105, Figs. 1-3.

Material No. 563. Locality: Hawaii, at Honolulu Fish Market. Date: September 7, 1961. Collector: W. L. KLAWE. Host: *Sphyraena barracauda* 13 lbs. in weight. External.

Eleven females all without egg strings and one male. Coloration: Brownish in formalin, becoming somewhat lighter toward caudal end. Measurements of females: 12.61 mm × 4.08 mm; 10.83 mm × 3.85 mm; 10.70 mm × 4.08 mm; 10.61 mm × 3.69 mm; 10.53 mm × 3.92 mm; 10.30 mm × 3.77 mm; 10.30 mm × 3.85 mm; 10.22 mm × 3.69 mm; 10. 00 mm × 3.92 mm; 9.48 mm × 3. 85 mm; 9. 48 mm × 3. 77 mm. Measurements of male: 6.93 mm × 3.46 mm.

Gloiopotes longicaudatus (MARUKAWA)

SHIINO 1954, pp. 273-278, Figs. 1-2. As for synonymy refer to SHIINO 1954.

Material No. 551. Locality: Costa Rica, 5 miles off the course abeam Cape Velas. Date: March 27, 1962. Collector: W. L. KLAWE. Host: A marlin 500-600 lbs. in weight, caught by night light. External.

Three females without egg strings and three males. Coloration: Whitish in formalin, scattered by brown pigments. The central part of the carapace and the genital segment in the region of the gonads are colored in yellowish brown. Eye pigment dark brown. Measurements of females: 9.16 mm × 4.46 mm; 8.93 mm × 4.49 mm; 8.85 mm × 4.30 mm. Measurements of males: 7.93 mm × 3.38 mm; 7.54 mm × 3.46 mm; 7.31 mm × 3.23 mm.

Material No. 552. Locality: Socorro Is., Revillagigedo Group, Mexico. Date: November 4, 1961. Collector: D. C. VANN. Host: Black marlin. On the external

surface.

Fourteen females and nine males. Coloration: As in material No. 551. Egg strings light yellowish brown. Measurements of females: 9.24 mm × 4.54 mm, egg string 3.16 mm long; 9.00 mm × 4.38 mm, egg string 3.16 mm long; 8.86 mm × 4.23 mm; 8.85 mm × 4.31 mm, egg string 2.77 mm long; 8.85 mm × 4.23 mm, egg string 3.00 mm long; 8.85 mm × 4.47 mm, egg string 3.38 mm long; 8.79 mm × 4.38 mm; 8.70 mm × 4.31 mm, egg string 3.38 mm long; 8.70 mm × 4.23 mm; 8.24 mm × 4.00 mm, egg string 2.46 mm long; 8.09 mm × 4.31 mm, egg string 3.15 mm long; 8.09 mm × 3.85 mm; 7.85 mm × 4.31 mm; 7.31 mm × 4.00 mm, egg string 2.54 mm long. Measurements of males: 7.93 mm × 3.76 mm; 7.46 mm × 3.31 mm; 7.38 mm × 3.00 mm; 7.31mm × 3.31mm; 7.31 mm × 3.31 mm; 7.15 mm × 2.92 mm; 7.15 mm × 2.85 mm; 6.69 mm × 3.31 mm; 6.85 mm × 3.08 mm.

Material No. 571. Locality: The Pacific, 16°50.5′S, 86°57.0′W. Station No. 14 in her twelfth cruise of "Shoyo Maru". Date: January 9, 1963. Collector: W. L. KLAWE. Host: *Makaira audex.* External.

Eight females and ten males. Coloration: Light yellowish brown in formalin, egg strings yellowish. Measurements of females: 11.30 mm × 5.23 mm; 11.16 mm × 4.92 mm; 11.15 mm × 5.23 mm; 11.00 mm × 5.23 mm, egg string 3.00 mm long; 10.92 mm × 5.30 mm; 10.52 mm × 5.00 mm, egg string 3.79 mm long; 10.52 mm × 4.92 mm; 10.48 mm × 5.38 mm, egg string 4.77 mm long. Measurements of males: 9.40 mm × 3.69 mm; 9.25 mm × 3.31 mm; 9.17 mm × 3.46 mm; 9.16 mm × 3.84 mm; 9.10 mm × 3.77 mm; 8.85 mm × 3.79 mm; 8.79 mm × 3.84 mm; 8.79 mm × 3.77 mm; 8.70 mm × 4.00 mm; 8.48 mm × 3.84 mm.

Material No. 578. Locality: Mancora, Peru. Date: May 18, 1960. Collector: W. L. KLAWE. Host: *Makaira* sp. External.

Four adult females, four adult males, three young females, and one female with defects caused by manupilation at the time of sampling. The females are without egg strings, but two detached strings were found in the vial. Coloration: Yellowish in formalin. Measurements of females: 9.64 mm × 4.69 mm; 9.64 mm × 4.54 mm; 9.55 mm × 4.62 mm; 9.48 mm × 4.69 mm; egg strings 4.00 mm and 4.08 mm long. Measurements of males: 8.10 mm × 3.61 mm; 8.01 mm × 3.77 mm; 7.85 mm × 3.61 mm; 7.79 mm × 3.69 mm. Measurements of young females: 6.44 mm × 3.39 mm; 6.31 mm × 3.39 mm.

Material No. 585. Locality: Mancora, Peru. Date: May 1960. Collector: W. L. KLAWE. Host: *Xiphias gladius.* External.

Three females. Coloration: Yellowish brown in the central region, becoming lighter toward the sides. Egg strings pale yellow. Measurements: 10.54 mm × 4.93 mm; 10.68 mm × 5.00 mm, egg string 3.85 mm long; 13.46 mm × 5.00 mm, egg string 3.92 mm long. In all the females the caudal rami are mutilated.

Pandarus satyrus DANA

DANA 1852, pp. 1367-1368, Pl. 95, Fig. 1; SHIINO 1954b, pp. 291-332; 1959b, p. 315. As for more

complete bibliography refer to SHIINO 1954b.

Material No. 556. Locality: Ecuador, approx. 35 miles northeast of Pasado. Date: April 2, 1962. Collector: W. L. KLAWE. Host: A "black-tipped" shark caught by night light.

Three females, two of which carry egg strings. Coloration: Carapace black in formalin, encircled by light yellowish brown marginal band, and with similar-colored areas on the postero-lateral angles. Ocular region is a transverse crescent of light color. Dorsal plates of the second to fourth segments are dark brown in the central region, which is surrounded by pale yellowish narrow marginal band. The genital segment is grayish brown and has caudo-lateral processes ending in a black tip. The ventral surface of the entire body is gray with pinkish tinge. The pads on the legs and the tip of the oral tube are tinged with vermilion red. Measurements: 8.70 mm × 4.16 mm, egg string 11.60 mm long; 8.16 mm × 4.08 mm, egg string 11.00 mm long; 8.04 mm × 4.00 mm.

Dinematura latifolia STEENSTRUP et LÜTKEN

STEENSTRUP and LÜTKEN 1861, pp. 378–380, Pl. 8, Fig. 16; SHIINO 1954b, pp. 308–312, Figs. 9–10. As for bibliography refer to SHIINO 1954b.

Material No. 565. Locality: The Pacific, 24°51.5′S, 103°16.0′W. Station No. 12 of the twelfth cruise of "Shoyo Maru". Date: January 22, 1963. Collector: W. L. KLAWE. Host: Unknown. The parasites were found on the deck.

Five females, two of which bear egg strings. The vial contains four detached egg strings in addition. Coloration: Whitish in the lateral region of the carapace and on the dorsal plates, the color growing darker toward the central region. Eyes dark brownish. The middorsal line is colored in black extending from the point just behind the eyes to the end of the genital segment. Gonads are seen through the skin of the genital segment in a dirty yellow color. Egg strings are light yellowish. Measurements: 11.39 mm × 6.55 mm, egg string 20.85 mm long; 11.00 mm × 6.31 mm; 10.91 mm × 6.55 mm, egg string 26.80 mm long; 10.78 mm × 6.31 mm; 10.31 mm × 6.46 mm.

Pseudocycnus appendiculatus HELLER

HELLER 1865, pp. 218–219, Pl. 22, Fig. 7; SHIINO 1954, 325–331, Figs. 24–25. As for bibliography refer to SHIINO 1954.

Material No. 572. Locality: The Pacific, 22°13′N, 110°46′W. Date: June 1, 1962. Collector: J. JOSEPH. Host: *Thunnus albacares* 983 mm long. Along the gill filaments.

Six females. Coloration: Dirty brown, egg strings similarly colored. Measurements: 11.38 mm × 1.08 mm, caudal appendage 3.77 mm long, egg string 27.4 mm long; 10.30 mm × 1.15 mm, caudal appendage 5.62 mm long, egg string 30.0 mm

long; 10.10 mm × 1.15 mm, caudal appendage 3.38 mm long; 9.79 mm × 1.31 mm, caudal appendage 3.77 mm long, egg string 27.1 mm long; 9.70 mm × 1.23 mm, caudal appendage 3.85 mm long; 9.70 mm × 1.23 mm, caudal appendage 3.77 mm long, egg string 26.6 mm long.

Brachiella thynni CUVIER

SHIINO 1956, pp. 283-287, Figs. 8-9; 1960a, p. 539. As for bibliography refer to SHIINO 1956.

Mat rial No. 559. Locality: Hawaiian waters, Honolulu, at the Fish Market. Date: September 12, 1961. Collector: D. C. VANN. Host: *Thunnus albacares.* On the axis of pectoral fin.

A female carrying a male and egg strings bursting. Coloration: Whitish in formalin. Measurements of female: from the head to the base of arms ca. 5.77 mm long, from the arm base to the body end 7.16 mm long, arm 4.15 mm long, neck 1.00 mm thick at the base, trunk 6.30 mm × 3.16 mm, caudo-ventral processes 6.69 mm and 6.39 mm long, caudo-dorsal processes 8.48 mm and 7.62 mm long.

Material No. 560. Locality: Hawaiian waters, Honolulu, at the Fish Market. Date: September 13, 1961. Collector: D. C. VANN. Host: *Parathunnus sibi.* On the axis of pectoral fin.

Nine females, two of which carry each a male. Coloration: Light yellowish white in formalin, genital segment somewhat darker. Egg strings brownish to yellowish. Measurements of the largest female: neck, from the head to the arm base 8.08 mm long, from the latter to the fore end of the trunk 2.69 mm long, neck 1.58 mm wide at the base, arm 7.70 mm long, 2.69 mm wide at the base, trunk 8.47 mm long, 1.92 mm wide at the fore end, 4.00 mm wide at the hind end, 2.46 mm thick, caudo-dorsal processes 14.00 mm and 15.00 mm long, caudo-ventral processes 9.93 mm and 8.08 mm long, egg strings 14.22 mm and 15.22 mm long.

Material No. 561. Locality: Hawaiian waters, Honolulu, at the Fish Market. Date: September 12, 1962. Collector: D. C. VANN. Host: *Thunnus obesus.* On the axis of pectoral fins.

Five females, two of these carrying each a male. Color as in material No. 559. Measurements have not been taken.

Material No. 564. Locality: Hawaii, Honolulu, at the Fish Market. Date: September 13, 1961. Collector: D. C. VANN. Host: *Thunnus albacares.* On the axis of pectoral fins.

Two females and a male. Coloration: Yellowish in formalin, with brownish egg strings. Measurements of larger female: neck, from the head to the arm base 5.69 mm, from the latter to the fore end of the trunk 2.00 mm, neck base 1.23 mm wide, trunk 5.15 mm long, 1.38 mm wide at the fore end, 3.46 mm wide at the hind end, arm 3.38 mm long, caudo-ventral processes 7.30 mm and 6.93 mm long, caudo-dorsal processes 8.17 mm and 7.70 mm long, egg strings 10.00 mm and 9.32 mm long.

Acknowledgement

I desire to express my obligation to Dr. W. L. KLAWE, the Senior Scientist in the Inter-American Tropical Tuna Commission and to Dr. James JOSEPH of the same Commission, both of whom kindly provided me with materials for my investigation.

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Vol. 4, No. 3, December 15, 1963

Parasitic Copepods of the Eastern Pacific Fishes

2. *Lütkenia elongata* sp. nov.

Sueo M. Shiino

(With Two Text-figures)

So far as I am aware, the genus *Lütkenia* Claus includes the sole valid species *L. asterodermi* Claus which has hitherto been known only from *Luvarus imperialis* Raf. in the Mediterranean and in the British Seas. Another species *L. integra* Richiardi, which is said to have been found on *Galeus canis* L. and *Mustelus equestris* Bt., is only nominal, and is accompanied neither with description nor with illustration. Last year, Dr. W. L. Klawe sent to me a couple of specimens of parasitic copepods found on *Luvarus imperialis* caught off the coast of California for identification. The specimens were fortunately consisting of a male and a female. The body of the female was proportionately far longer than in any of the specimens described and figured by Claus (1864) and by T. Scott and A. Scott (1913) as well as than in the form recorded by Heller (1865) under the specific name of *Cecropsina glabra* Heller, which was synonymized by Brian (1906) with *Lütkenia asterodermi*. Besides, the male was different from that represented in Claus' and Heller's figures in the configuration of the genital segment. Although the present specimens were obtained from the same host species as the one on which *asterodermi* was found, I dare propose a new species for them on account of those important differences.

Lütkenia elongata sp. nov.

(Figs. 1–2)

Locality: The Pacific, 32°38′N, 117°57′W. 35 miles bank off the coast of Lower California.

Date: August 21, 1962.

Host: *Luvarus imperialis* Raf. ca. 510 mm long, caught in a purse-seine net. The parasites were found on the surface of the host.

Collector: W. L. Klawe and F. G. Alverson of the Inter-American Tropical Tuna Commission. The host was given to them by James Nagle of m/v Santa Rosa.

Specimens: No. 555. One female and one male. They are lodged in the Prefectural University of Mie.

Coloration: The female is opaque, light yellowish brown in formalin. The male is lighter in color, almost white and semitransparent.

Measurements: Female. Entire length up to the end of caudal furca 20.00 mm. The carapace 5.73 mm long from the fore margin to the end of the lateral lobes, 5.10 mm long on the middorsal line, and 6.88 mm wide. The third segment 2.40 mm long, 3.54 mm wide in the anterior region, 1.56 mm wide in the posterior region. The fourth segment 1.58 mm long from the fore end to the base of dorsal plates, 1.88 mm wide across the limb bases, and the dorsal plates 7.80 mm × 2.19 mm. The genital segment 13.10 mm long from the bases of the dorsal plates of the fourth segment to the ends of the same plates of its own; the length from the named point to the end of the segment, measured on the middorsal line 5.42 mm; the length from the bases of the fourth legs to the fore end of the abdomen, measured on the midventral line 4.89 mm; the dorsal plates 7.29 mm long from the hind end of the segment to the end of the plates, 2.70 mm wide in the right plate, 2.92 mm wide in the left plate, and the width combining both the plates 6.03 mm. The caudal furca 3.13 mm × 1.67 mm. Male. Entire length up to the end of caudal furca 9.48 mm. The carapace 5.30 mm long from the fore margin to the ends of the lateral lobes, 3.95 mm long on the middorsal line, and 5.30 mm wide. The third segment 1.56 mm × 2.61 mm. The fourth segment 0.94 mm long on the middorsal line, 0.83 mm wide at its fore end, and the length and width including the dorsal plates 1.12 mm × 1.77 mm. The genital segment 1.77 mm long on the middorsal line, 2.19 mm long inclusive of the caudo-lateral lobes, 1.56 mm wide at the fore end, and 1.98 mm wide near the caudal end. The abdomen 0.83 mm × 1.02 mm. Caudal furca 0.73 mm × 0.36 mm.

Female: Holotype. The body is much longer than in the male, reaching about twice the length of the latter. Since the two sexes do not show so great a difference in the size of the carapace, the elongation of the female owes to the excessive development of the posterior segments. The carapace and genital segment are more or less convex dorsally, and not so flattened as in *Caligus* or *Lepeophtheirus*. The right dorsal plate of the fourth segment is mutilated near the base.

The carapace is orbicular in outline, shallowly notched in front on the median, and has a large trapezoid excavation in the rear. The frontal plates are short and narrow. The lateral areas of the carapace extend backward for some distance beyond the rear margin of the central area forming a pair of linguiform lobes. The free margins show slight undulation besides carrying a notch at about the middle. The central area is thrice as wide as the lateral ones, from which it is bordered by a pair of curved ribs disposed like parenthesis and ending some distance behind the fore margin of the carapace. The eyes are located a little in front of the middle of the central area. A short transverse rib traverses each lateral area, combining the marginal notch with the longitudinal rib and inclining somewhat rearward. The posterior border of the carapace retreats a little toward the front in the middle region. The marginal rims of the two sides are narrow, and distinct only in the posterior region.

The second segment is fused with the carapace, but the third is distinct. The

latter is expanded anteriorly into a pair of quadrate lobes, but narrowed posteriorly, and connected with the succeeding segment through a narrower, short waist. The segment possesses a pair of undulating longitudinal ribs on the dorsal surface along the bases of the lateral lobes. Each of the lobe carries a narrow marginal rim, which, after encircling the posterior angle of the lobe, extends antero-internally over the dorsal surface. The limbs are attached to the segment in its anterior expanded region.

The fourth segment is short and narrow, but carries a pair of elongate dorsal plates, which are directed straight backward, reaching beyond the end of the succeeding segment. Although the right member is mutilated, the two plates are believed to run parallel with each other, terminating in a narrowly round end.

The genital segment is strongly elongated and longer than the carapace. It is narrowed in front to continue to the preceding segment, but is gradually widening caudally so as to be prolonged into a pair of large parallel dorsal plates, which are even longer than the segment proper and of uniform width. These plates are longer and broader than the corresponding plates of the fourth segment, covering the abdomen and caudal furca almost entirely from above, and terminate in truncate ends.

The abdomen is large in size, about as long as the carapace, and one and half times as long as its own width. It is attached to the ventral surface of the genital segment just in front of the middle of the length inclusive of the dorsal plates, and is suspended by a short, strongly narrowed stalk, from which it rapidly widens backward expanding into a shield-like flattened segment. It bears a shallow notch on either lateral margin about the middle and is produced into a low inconspicuous bulge at either caudo-lateral angle. The caudal furca is large in size, lamellar and oblong ovate. The hind margin of the furca is sinuous and armed with four short plumose spines, with which are associated two much feebler spines, locating one on each side of them.

The first pair of antennae are relatively small, entirely exposed in dorsal aspect. The first segment of this pair is not much dilated and is provided with two rows of short plumose spines along the anterior border; the second segment is rod-shaped and tipped by a small number of short simple spines. The second antennae are two-segmented. The basal segment is short but thick, and the terminal segment is well curved like a hook and is strongly chitinized, exhibiting a dark brown coloration at the tip. The latter segment carries a tiny spinule about its middle. The oral tube is slender and elongate, enclosing styliform mandibles. The second maxillae are situated just outside the base of the oral tube and have a rod-like basal segment which issues a tiny spiniform segment from the apex outward. The first maxillipeds are relatively feeble and tipped by a thick flagellum which is accompanied at the base with two shorter, subequal accessory flagella. All the flagella are fringed along their borders by finely serrated rims. The second maxillipeds are powerful chelae, which consist of a swollen palm and a well curved,

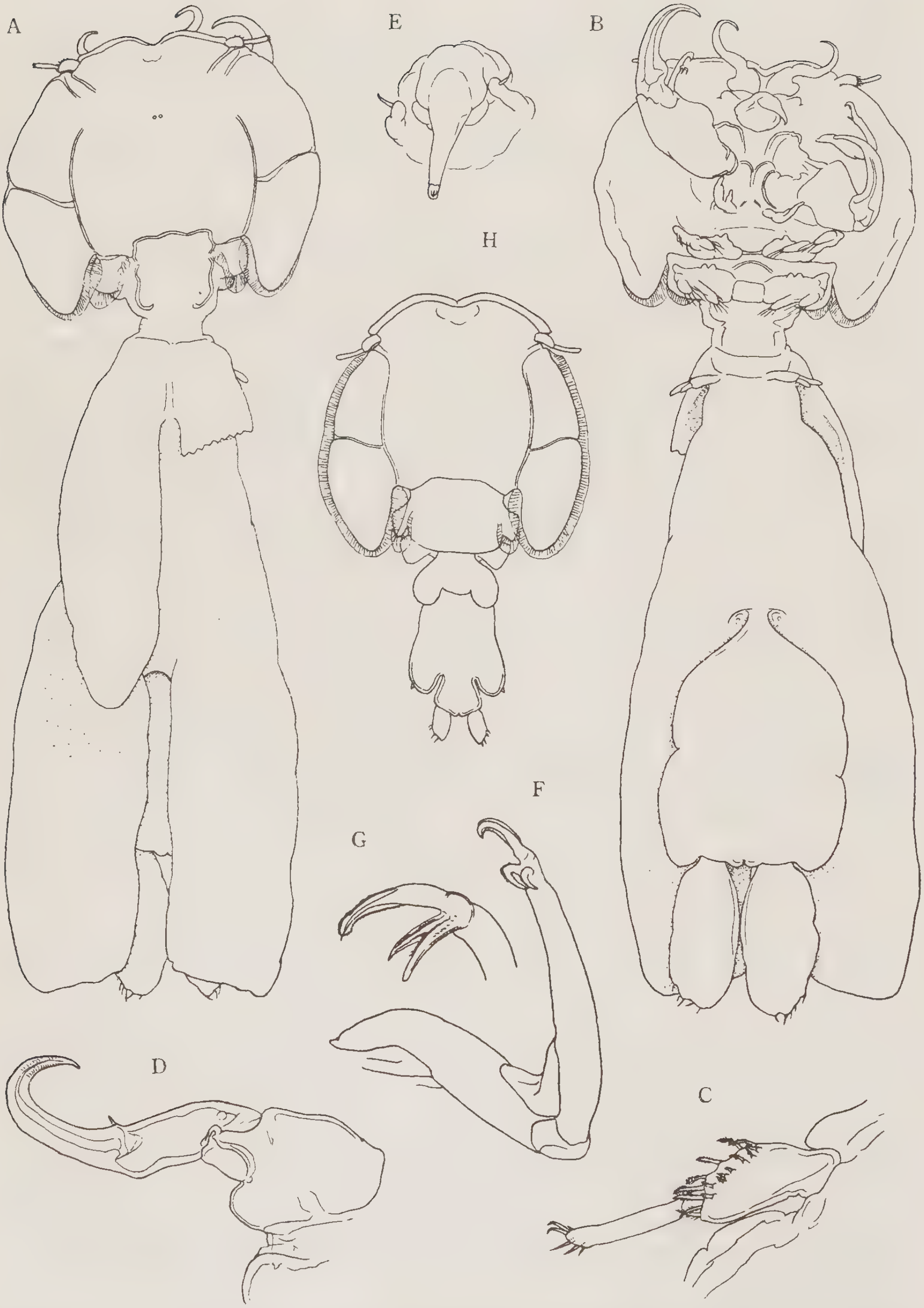

Fig. 1. *Lütkenia elongata* sp. nov. A, female, dorsal aspect; B, same, ventral aspect; C–G, female; C, first antenna, ventral aspect; D, second antenna; E, mouth tube with second maxillae; F, first maxilliped; G, apex of same; H, male, dorsal aspect. A, B, H ×7.2; C, G ×47; D, E, F ×38.

strongly chitinized claw of a dark brown color and reaching the base of the palm when closed.

Four pairs of legs are substantially the same as the corresponding pairs of the male in structure except for that the second exopodite segment of the third pair is lacking in the claws which are encased in the interior of the external cuticle (cf. the male appendages). The rudiments of the fifth or sixth pairs of legs are absent.

Male: Allotype. As compared with the female, the body of the male is strongly shortened owing to reduction of the size of posterior segments, and the carapace plus the third segment occupy more than half of the entire length. The carapace is as long as wide and relatively narrower than in the female. The fore margin is prominently arched, though shallowly depressed on the median, and is furnished with narrow frontal plates which occupy far greater part of the margin as compared with those of the other sex. The lateral lobes reach the posterior limit of the third segment. The medio-posterior margin is gracefully arched forward.

The third segment, which is distinct from the carapace, has a pair of quadrate, somewhat posteriorly inclining lateral lobes, and is evenly round on the posterior border. The limb bases are partly visible from above extruding just behind the lateral lobes as a pair of lamellae of similar shape.

The fourth segment is narrower than the third, with which it is connected by a short, narrowed neck, and is furnished with a pair of small oval dorsal plates which are apart from each other.

The genital segment is shorter than a half of the carapace length and longer than its own width. It is nearly quadrate in form, being deprived of the dorsal plates, but is slightly widening toward the hind end, where it is produced into a pair of oval lobes on either side of the abdomen.

The abdomen is small, pentagonal in form having a V-shaped caudal margin, and is not bordered from the preceding segment by a distinct line of demarcation. Proportionately with the smallness of the abdomen, the caudal furca is much reduced in size. In addition to the ordinary number of spines present in the female, the furca bears another tiny spinule on the ventral surface some distance apart from the base, and transverse rows of tiny hairs arranged along the outer margin.

Without showing any appreciable sexual differences, the cephalic and postcephalic appendages resemble those of the female in their constitution.

Of four pairs of legs which are biramous and relatively small in size, the first two pairs are attached to the ventral surface of the carapace. Both the rami of the first three pairs are more or less dintinctly two-segmented, while those of the last are one-segmented. The exopodite of the first pair is narrow but elongate, whereas the endopodite is much reduced in size, being composed of tumid basal and rod-like apical segments. Both the rami are sparingly setose. Development of natatory spines is restricted to the second and third pairs, which resemble the corresponding pairs of *Caligus* in general constitution. The broad protopodites of both sides are combined together by the insertion of similarly exapanded sternal plate, and the excessive development of those structures in the third legs results in the

Fig. 2. *Lütkenia elongata* sp. nov. A–B, female; A, second maxilliped; B, end of left caudal furca; C–H, male; C, first leg; D, second leg; E, third leg; F, fourth leg; H, right caudal furca. A, B ×21; C–G ×93; H ×53.

formation of a basal apron. The fourth pair of legs are much smaller than other legs. The members of the two sides are widely apart at their bases, and the stout protopodite issues larger exopodite and smaller endopodite, both lamellar and one-segmented. The disposition of spines and hairs with which four pairs of legs are armed is diagrammatically illustrated in Table 1.

Table 1. Disposition of armatures on four pairs of legs.

Legs	Border	Sternal plate	Protopodite	Exopodite		Endopodite	
				I	II	I	II
I	outer		1h	1h	4h		3rh
	inner		1h		3rh		
II	outer	c	1rp	CC, 1H	C, 4H	c	c, 6P
	inner		1P, c	c, 1P	5P	1P	c, 1P
III	outer	c	CC, 1rp	C, 1H	C, 3H		1h
	inner		c		c, 3P, 1p		3p
IV	outer		1h	C, 1h, C, 2h		2rh	
	inner			4h		3h	

Abbreviations: C, row of spinules; CC, area covered with spinules; c, row of fine hairs, H, large simple spine; h, small simple spine; P, long plumose spine; p, short plumose spine; rh, very tiny spine; rp, very tiny plumose spine. Roman numerals represent the ordinal numbers of the legs or segments, and arabic numerals the number of spines present on them.

The exopodite segments of the second and third legs show a sharp serration on the outer border, and the outer spines on them are doubly edged with pectinated rim. The outer distal angle of the first exopodite segment of the second legs and the same angle of the protopodite of the succeeding legs are covered by short spinules extending over some small area. The second endopodite segment of the third pair is somewhat indistinctly separated from the first segment, and is armed with three hooks, which are largely enclosed under the external chitin of the segment protruding from the surface only a little. The rami of the fourth legs as well as their armatures are much shrivelled. The exopodite has a notch on the outer border, presumably indicating the site of fusion of component segments. Such a notch is absent from the endopodite. The fifth, or sixth leg rudiments are represented by a pair of ridges, each of which runs on the ventral surface of the caudolateral lobe of the genital sement obliquely backward, and is raised at the end into a short rod protruding a little beyond the margin and terminating in two small unequal spines.

Remarks: As the dissection of the sole couple was not desirable, the thoracic legs were illustrated from the male which had semi-transparent body. The corresponding legs of the opaque female were substantially the same in structure according to the observation by a reflected light.

Lütkenia asterodermi was obtained by Claus (1864) from *Asterodermus coryphaenoides* which in Brian's (1906) opinion was nothing but a young stage of *Luvarus imperialis*.

It was recorded by T. and A. Scott from the same host species in the British Seas and by Brian from *Asterodermus elegans* Risso in the Mediterranean. Heller's *Cecropsina glabra* which is a synonym of *L. asterodermi* was taken from an unknown host in the Adriatic Sea. As stated before, all the females of *asterodermi* have the body much shorter than the present one, this being due to the shortening of the segments from the fourth backward. Judging from the figures given by those authors, these segments are about as long as, or a little longer than the carapace (body length 10–11 mm after Claus), or one and a third times as long as this (body length 10 mm after Heller), or less than one and a half times as long (body length unknown in T. and A. Scott's specimen). In the present female these segments reach nearly two and a half times the carapace length, having much more prolonged dorsal plates, and the body measures 20 mm. In the known males of *asterodermi* the genital segment is ovate with well rounded sides, whereas in the present male this is nearly quadrangular in shape, having two sides almost parallel and ending in distinctly bilobed caudal end. Despite that the present specimens were found on the type host species of *asterodermi*, these differences may be considered enough to warrant the establishment of a new species.

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Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 4, No. 3, December 15, 1963

Parasitic Copepods of the Eastern Pacific Fishes

3. *Echthrogaleus pellucidus* sp. nov.

Sueo M. SHIINO

(With Four Text-figures)

In his revision of the family Pandaridae, WILSON (1907) included eight valid species in the genus *Echthrogaleus* STEENSTRUP et LÜTKEN. It does not appear that any other species has been added to this genus after that except *E. lütkeni* (NORMAN) which was represented by the male alone and was not comprised in his list. While examining the specimens of the parasitic copepods collected by Dr. W. L. KLAWE off the coast of Ecuador, I came across very interesting forms, which were considered to belong to this genus, but could not be referred to any of the known species. As the material comprised the adults of both sexes and the juvenile stages in a number ample for dissection, I will give here a detailed description, proposing a new species for them.

Echthrogaleus pellucidus sp. nov.

(Figs. 1–4)

Locality: The Pacific. Plata Island, Ecuador bears 183° t., off 24 1/2 miles.

Date: April 13, 1962.

Host: Thresher shark caught by night light. On the outer surface.

Collector: W. L. KLAWE of the Inter-American Tropical Tuna Commission.

Specimens: 14 adult females, 3 juvenile females, 16 adult males and 7 juvenile males.

Coloration: The female body semitransparent; the carapace white, with light brownish coloration in the central region; the genital segment brownish; all pairs of dorsal plates colorless; ventral bosses of the carapace and appendages vivid brown in color; egg strings yellowish. The male transparent and similar to, but somewhat lighter than the female in color; sperm sacs in the genital segment yellowish to brownish; ventral bosses of the carapace not so deeply colored as in the female. Juvenile stages much lighter than the adults in color.

Measurements: Female holotype. Entire length 5.38 mm. The carapace 2.14 mm long on the middorsal line, 2.00 mm long excluding frontal plates, 2.98 mm from the fore margin to the ends of lateral lobes, and 3.42 mm wide; frontal plates 0.19 mm × 2.04 mm. The second and third segments 0.67 mm × 2.19 mm. Dorsal plates of the fourth segment 2.81 mm wide along the fore margin, 3.05 mm wide

across the widest region; a single dorsal plate 1.24 mm × 1.43 mm. The genital segment 1.86 mm long on the middorsal line, 1.90 mm wide, from the fore end to the hind end of the caudal lobes 2.43 mm long. The abdomen 0.86 mm long, 0.90 mm wide at the fore end, 0.50 mm wide at the hind end. Egg strings 15.5 mm long. Male allotype. Entire length 4.38 mm, same including caudal rami 4.86 mm. The carapace 1.95 mm long on the middorsal line, 1.76 mm long excluding frontal plates, 2.67 mm long from the fore margin to the ends of lateral lobes, and 2.80 mm wide; the frontal plates 0.19 mm × 2.10 mm. The second and third segments 0.62 mm × 1.57 mm. The fourth segment 0.24 mm on the middorsal line, 0.38 mm long including dorsal plates, and 0.81 mm wide. The genital segment 1.05 mm × 0.91 mm. The first abdominal segment 0.19 mm × 0.43 mm and the second segment 0.33 mm × 0.33 mm. Caudal rami 0.52 mm × 0.14 mm. Juvenile female. Entire length 3.48 mm. The carapace 2.28 mm on the middorsal line, 2.14 mm long excluding frontal plates, 2.43 mm long from the fore end to the ends of lateral lobes, and 2.62 mm wide; frontal plates 0.14 mm × 1.57 mm. The second segment 0.24 mm × 1.62 mm. The third segment 0.33 mm × 1.05 mm. The fourth segment 0.26 mm long on the middorsal line, 0.52 mm long including dorsal plates, and 1.14 mm wide. The genital segment 0.62 mm long on the middorsal line, 0.81 mm long including lateral lobes, and 0.72 mm wide. The abdomen 0.29 mm × 0.38 mm. Juvenile male. Entire length 3.14 mm. The carapace 1.67 mm long on the middorsal line, 2.24 mm long from the fore margin to the ends of lateral lobes, and 1.85 mm wide. The second segment 0.33 mm long on the middorsal line, 0.67 mm long up to the tip of lateral lobe, and 1.14 mm wide. The third segment 0.33 mm × 0.86 mm. The fourth segment 0.33 mm × 0.62 mm. The genital segment 0.33 mm × 0.71 mm. The abdomen 0.34 mm × 0.33 mm.

Female: Holotype. The body is flattened, with the dorsal integument much less strongly chitinized than in other species of *Echthrogaleus*. The carapace is orbicular in outline, having two sides evenly curved except for a notch about the middle, and is circumscribed with a narrow marginal rim. The frontal plate is three fifths as wide as the carapace, arched in front with a distinct median notch, and is margined by very narrow rim. The central area of the carapace is broad, occupying two-thirds of the entire width, and is demarcated from the lateral areas by a pair of parallel ribs which are turned inward near the fore ends. The posterior border of this area is almost straight, armed with a small number of feeble denticles, and carries a pair of small irregular-shaped, membraneous flaps, movably articulated to the extreme lateral angles. Each of the lateral areas is traversed about the middle by a transverse rib and ends in a narrowly rounded lobe which extends backward a little beyond the third segment. The eyes are situated a little in front of the centre of the carapace.

The second and third segments are coalesced together and distinct from the carapace. The second segment is produced on either side into a more or less quadrate plate, which is fringed by a narrow striated membrane encircling the

Fig. 1. *Echthrogaleus pellucidus* sp. nov., female. A, female, dorsal aspect; B, ventral aspect; C, dorsal plate of fourth segment, dorsal aspect; D, same, lateral aspect; E, postero-lateral region of carapace, showing its dorsal flap; F, first antenna; G, second antenna and mouth tube; H, first maxilliped; I, second maxilliped. A ×16; B ×21; C, D ×135; E ×30; F ×74; G-I ×58.

posterior and lateral margins. The third segment is much narrower than the second and has no lateral projection, but carries a pair of slight bulges on the posterior border which are the remnants of the dorsal plates.

The fourth segment is expanded dorsally into a pair of dorsal plates of a rhomboidal shape, which, covering the genital segment, extend to the middle of the latter. Each of the plates is entire on the anterior margin, but is produced at the extreme lateral angle into a sharp denticle. The median and posterior sides of the plate are beset with a series of sharp recurved spines, which are more or less obliterated on the lateral side.

The genital segment is enlarged, but shorter and far narrower than the carapace. It is narrowed from the wider anterior region gradually backward, and is produced at the caudal end into a pair of oblong oval lobes surpassing the abdomen. The egg strings reaching thrice the length of body are suspended from the ventral surface of the genital segment at the bases of those lobes. The sixth segment is exposed on the dorsal side as a small semicircular plate present at the bottom of the median crevice between those lobes of the preceding segment and just in front of the abdomen.

The abdomen is flattened, wider anteriorly than posteriorly, about as long as wide, and trapezoid in shape. It is attached by a short, narrowed stalk to the ventral surface of the genital segment, beneath which it is entirely concealed. The antero-lateral angles of the abdomen are rounded, the sides are only slightly curved, and the caudal margin is nearly straight. The caudal rami are oblong, quadrangular, and terminate in three short plumose spines which are accompanied on the outside with a tiny plumose and somewhat longer simple spines and on the inside with a tiny simple one. The spermatophores are filiform bodies attached to the ventral face of the genital segment just in front of the abdomen.

The first pair of antennae are small in size. The basal segment of this pair is fringed by a row of short spines beset with fine hairs on its outer margin and has two additional rows of similar but much shorter ones internally to that row. The apical segment is rather slender, ending in a few feeble spinules. On the ventral surface of the carapace close behind the base of each antenna there is an oval corrugated boss. The second antennae are stout, three-segmented. The apical segment is strongly curved like a hook with sharp tip, and carries near the base two hairs arranged proximo-distally. The basal segment is associated just behind with an oval boss present on the sternal surface. The mouth tube is elongated and tubular. The first maxillae are absent. The second maxillae are placed just outside the base of the mouth tube, and are composed of thick base with two short spinules and unguiform laterally directing apex. The first maxillipeds are geniculated appendages as usual. The distal segment of the maxillipeds bears near the end a round protuberance thickly covered with tiny spinules, and ends in two unequal flagella, both rimmed with narrow pectinate membranes. The second maxillipeds are powerful prehensile limbs. Their terminal claw is relatively short, broad and flat-

Fig. 2. *Echthrogaleus pellucidus* sp. nov., female. A, first leg; B, second leg; C, outer margin of endopodite of same; D, third leg; E, two rami of same, dorsal aspect; F, fourth leg; G, caudo-lateral lobe of genital segment, showing sixth leg rudiment, ventral aspect; H, tip of the same leg. A, B, D–F ×74; C ×382; G ×46; H ×135.

tened, and is divided at the apex into two blunt unequal laminae. The claw is traversed at the base by a transverse row of short cirri. The basal segment is swollen, strongly chitinized in the distal portion, and uneven on the surface owing to the development of tubercles. These are disposed one in the region opposite to the bifid end of the claw, another laterally to this, and again another near the base of the claw, projecting over the surface as an oval process. The basal segment is provided further with a corrugated boss near the base and with another larger one on the sternum just in front of the base and outside the midventral line.

Four pairs of thoracic legs biramous. The two rami are two-segmented in the first pair and one-segmented in the last. In the other pairs the exopodite is three-segmented, whereas the endopodite is two-segmented, though a notch present on the outer border of the second segment suggests the site of fusion with the third segment. The protopodites of both sides in these pairs are combined with each other by the insertion of a broad sternal plate, which in the third legs forms together with the strongly expanded protopodites a continuous basal apron. The first three pairs of legs are armed with plumose natatory spines on their rami, and with corrugated bosses on the protopodite. The bosses are present in the first pair two on the protopodite and one on the first endopodite segment, whereas in the others they are three on the protopodite. The last pair of legs are much different from the others in their constitution. They have lamellar rami which are armed with simple short spines instead of plumose ones, and are lacking in the corrugate bosses on the protopodite.

The armatures on those four pairs of legs are shown diagrammatically in the Table 1.

The simple spines with which the first three pairs of legs are armed are for the greater part doubly edged by finely pectinate rim. The two rami of the second

Table 1. Armatures on four pairs of legs of the female.

Legs	Border	Sternal plate	Protopodite	Exopodite			Endopodite	
				I	II	III	I	II
I	outer inner		1p, 1B 1p, 1B	1H	CC, 4H c, 3P		1B	CC C, 3P
II	outer inner	C	2B, 1h 1B	CC, 1H 1P	C, 1H 1P	3H 4P	CC 1P	C c, 1p, 7P
III	outer inner	f	CC, 1rp, 2B 1H, f, 1B	C, 1H c, 1P	C, 1H c, 1P	C, 3H 5P	c 1P	c 6P
IV	outer inner		CC, 1h	CC, 2H C, 2h, 4H			CC C, 4H	

Abbreviations: B, corrugated boss; C, row of spinules; CC, area covered with spinules; c, row of hairs; f, membraneous flange; H, stout simple spine; h, feeble simple spine; P, stout plumose spine; p, feeble plumose spine; rp, very tiny plumose spine. Roman numerals denote the ordinal numbers of legs or segments, and the arabic ones the number of armatures present on them.

legs are thickly beset with fine spinules along their outer margin. The spinules extend internally to cover some area of the basal segment of both exo- and endopodites. The exopodite of the third pair is rimmed with finely pectinate membrane on the outer borders of all segments. The last pair of legs bear fine spinules on the outer marginal area on both the rami. The rudiments of the fifth legs are represented by a pair of styliform processes which are present on the genital segment on the ventral surface of the caudal lobes. Each of them ends in a stout claw associated with three tiny plumose spinules.

Male: The body is shorter and narrower than in the female and is much reduced in the size of posterior segments. The carapace resembles that of the female in general constitution, but has relatively larger frontal plate and smaller posterodorsal flaps. The second and third segments are united together into a single segment which is provided with quadrate lateral lobes.

The fourth segment is small, one third as wide as the carapace. It possesses a pair of small circular dorsal plates, which are separated from each other by the intervening straight hind border and cover only a small anterior part of the genital segment.

The genital segment is about two fifths as long as the carapace, longer than wide. It has the two sides evenly curved inward at the anterior end, and is produced a little in front of the caudal end into a pair of short lateral processes, from which the sides converge backward showing somewhat uneven outline.

The abdomen consists of two segments. The first segment is short, wider than long, about half as wide as the preceding segment and narrowing backward. The second segment is quadrate, longer than the first. The caudal rami are much narrowed, but elongate, and longer the abdomen, ending in four long plumose hairs which are accompanied on either side by a similar but far shorter one. The rami are lined with short hairs on the inner border.

The corrugated bosses on the carapace and appendages are similar to those of the other sex in their arrangement, but are somewhat more feebly chitinized. The terminal segment of the second antennae is sharper, more strongly incurvated, and has stouter spines than in the female. The claw of the second maxillipeds is longer and slenderer, ending in a simple sharp apex. The palm has three bosses arranged side by side on the inner edge against which the claw closes, but is devoid of oval process on the posterior side.

The first three pairs of legs are in accord with the corresponding pairs of the female in structure except for the following minor discrepancies. The first pair are deprived of spinules in the outer marginal area of the second exopodite segment, and the outer row of spinules on the endopodite is replaced by a row of hairs. The first exopodite segment of the second legs is lacking in the spinulose area, and the outer spinules on the endopodite are substituted by rows of hairs. The protopodite is hairy on the inner margin and the sternal plate is fringed by a membraneous flange. The endopodite of the third legs is unsegmented, though the fused segments

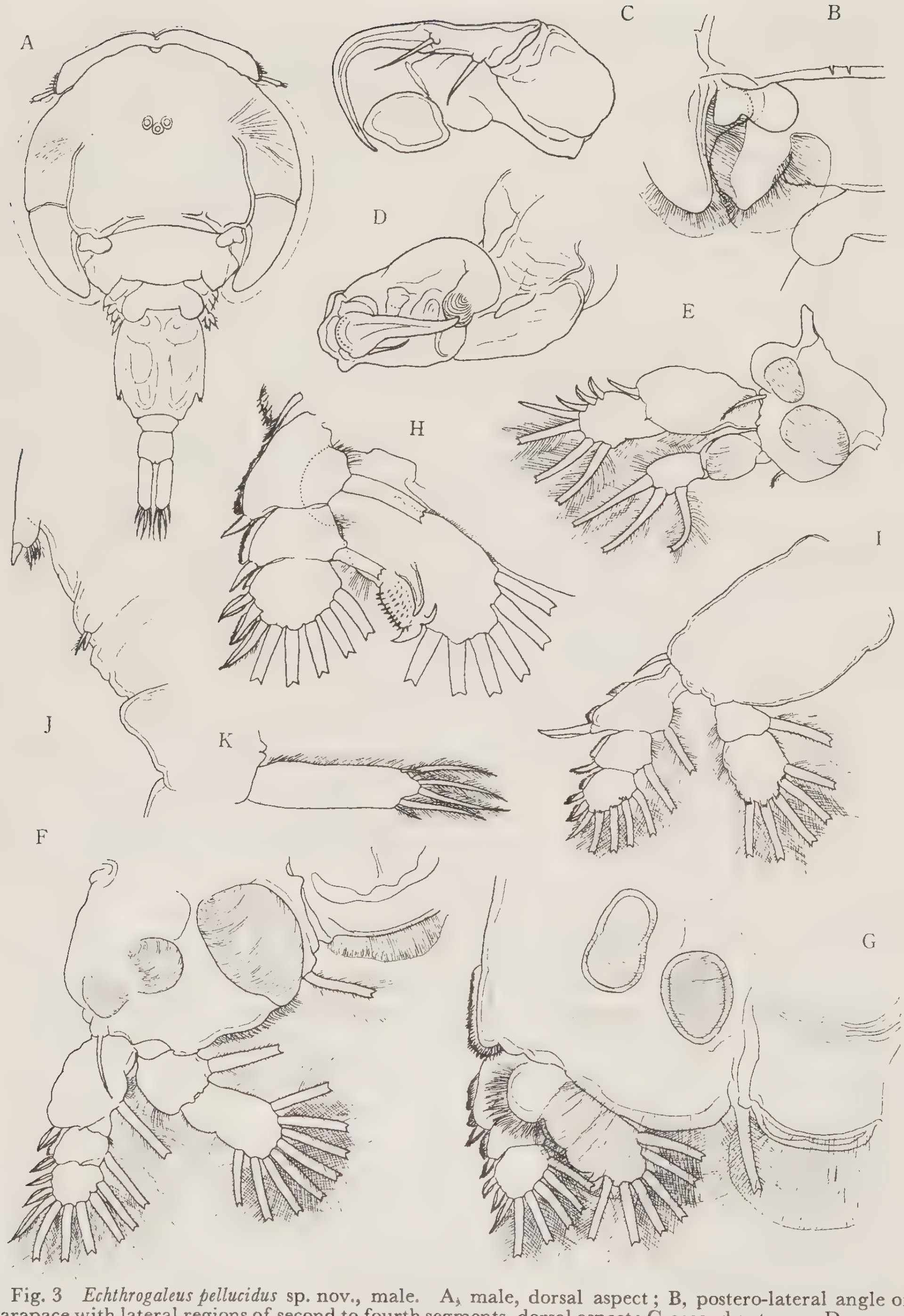

Fig. 3 *Echthrogaleus pellucidus* sp. nov., male. A, male, dorsal aspect; B, postero-lateral angle of carapace with lateral regions of second to fourth segments, dorsal aspect; C, second antenna; D, second maxilliped; E, first leg; F, second leg; G, third leg; H, two rami of same, dorsal aspect; I, fourth leg; J, caudo-lateral angle of genital segment, showing fifth and sixth legs, ventral aspect; K, caudal ramus. A ×16; B ×30; C ×74; D ×58; E-G, I, J ×93; H ×135; K ×46.

are indicated by the notches on the outer border. It bears on this border near the end an oval area covered by tiny spinules, around which the surface is raised into three unequal recurved spines. The fourth pair of legs are entirely different from those of the female in constitution. The two rami are not simple lamellae, but distinctly segmented and armed with well-developed natatory spines. The exopodite is three-segmented, while the endopodite is two-segmented. The disposition of spines and other armatures in this pair of legs is indicated in Table 2.

Table 2. Armatures on the fourth leg of the male.

Leg	Border	Protopodite	Exopodite			Endopodite	
			I	II	III	I	II
IV	outer inner	1h	2C, 1H c, 1P	C, 1H c, 1P	C, 2H, 1p 4P	c 1P	c c, 5P

Abbreviations as in Table 1.

The plumose spines on the distal segment of both the rami of the fourth legs are accompanied at their bases by a small pectinate lamina, or by a row of spinules. The fifth leg rudiments are represented by the lateral processes of the genital segment, each of which ends in a simple claw associated with three short plumose inner hairs. The sixth legs are small processes located on the ventral side of that segment behind the fifth legs. They are tipped by a simple spine as well as by a plumose one.

Juvenile female: The body is far shorter than in the adult. The length from the second segment to the caudal end is equal to the middorsal length of the carapace. The frontal plate bears a *Chalimus* filament. The paired flaps of the carapace is relatively smaller than in the adult. The second segment, which is here distinct from the third, has squarish, caudo-laterally directing, lateral lobes. The third segment is narrower than the second and cuneiform on the sides. The fourth segment is again wider than the preceding, yet narrower than the second, and bears a pair of small round dorsal plates apart from each other. The genital segment is shorter than the preceding three segments combined together, longer than wide and bilobed behind, forming a large median sinus, into which the short abdomen is inserted. The latter is squarish and wider than long.

The second maxillipeds, the first three and the fifth legs are in accord with the corresponding limbs of the abult in their constitution. The fourth legs are much different in retaining short natatory spines on both the rami. The exopodite is indistinctly two-segmented, but the endopodite is one-segmented. The armatures on this pair of legs are shown in Table 3. The exopodite bears two short rows of tiny hairs at the bases of the plumose spines and the endopodite carries three pectinate laminae near the terminal margin.

Juvenile male: The body is ovate, with posterior segments relatively broad. The carapace is prominently arched in front, and narrower than in the adult due

Table 3. Armatures on the fourth leg of the juvenile female.

Leg	Border	Protopodite	Exopodite		Endopodite
			I	II	I
IV	outer inner	c	c, 1rh, 1H 2P	c, 4H 3P	c, 3P 1p, 1P

rh, feeble simple spine, other abbreviations as in Table 1.

to the reduction in the width of lateral areas. The median length of the carapace is a little smaller than that of the rest segments combined together. The frontal plates are widening outward. The second to fourth segments are subequal in length to one another, but gradually narrowing from before backward. The second seg-

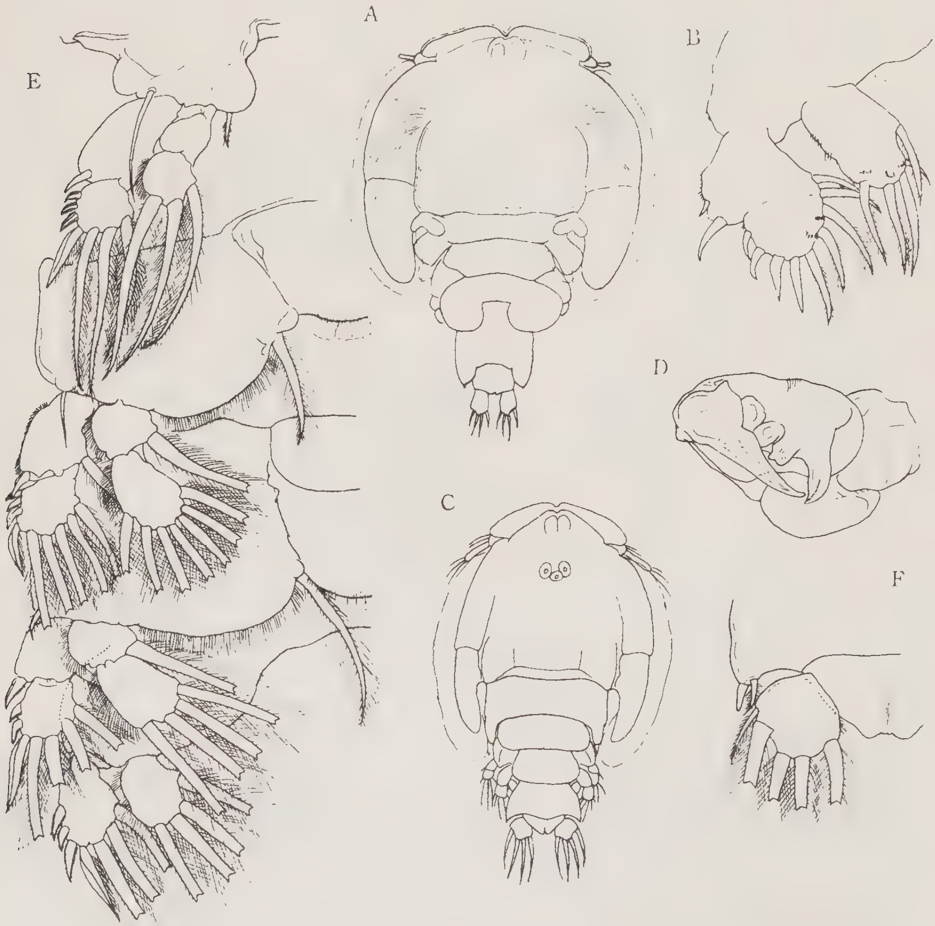

Fig. 4. *Echthrogaleus pellucidus* sp. nov., juvenile stages. A, juvenile female, dorsal aspect; B, same, fourth leg; C–F, juvenile male; C, dorsal aspect; D, second maxilliped; E, first to fourth legs; F, caudal ramus. A, C ×16; B ×135; D ×58; E ×93; F ×74.

ment is produced on either side into a narrow posteriorly directing lobe. The other segments have round sides. The genital segment is twice as wide as long, widening posteriorly, and acute at either caudo-lateral angle. The abdomen is small, twice as wide as long and triangular in shape. The caudal rami are short, but broad, and attached to the sides of the abdomen. The rami are armed with four well-developed apical and a short outer spines, all plumose in nature.

The first antennae are relatively well developed, carrying hairs longer than in the adult. The second maxillipeds are somewhat different from those of the adult in structure. The basal segment is produced opposite to the tip of the claw into an elongate, acutely pointed process, and is reinforced, further, with three irregular-shaped tubercles, arranged in line extending from the base of the claw to that process. The posterior side is swollen into a large bulge.

Four pairs of legs show the constitution somewhat different from those of the adult, and are armed with well-developed natatory spines. Both exo- and endopodites are two-segmented in all pairs except the last where they are unsegmented. The armatures on the legs may be seen from the diagram in Table 4.

Table 4. Armatures on four pairs of legs of the juvenile male.

Legs	Border	Sternal plate	Protopodite	Exopodite		Endopodite	
				I	II	I	II
I	outer		1h	1H	4H		c
	inner		1rp		3P		3P
II	outer	f	1h	c, 1H	4H	c	c
	inner		1P, c	1P	5P	1P	7P
III	outer	f	1rp	1H	3H	c	c
	inner		1P, c	1P	4P	1P	4P
IV	outer			4H		c	
	inner			3P		4P	

Abbreviations as in Table 1.

The outer spine on the first protopodite is rather long. Of the outer spines on the exopodites of all the legs, the distalmost is rimmed with narrow outer membrane and inner row of setae. The fifth legs are absent. The sixth legs are represented by two short spines, one simple and the other plumose, which are present at the caudo-lateral angles of the genital segment.

Remarks: The new species is distinguished from the known species of the genus *Echthrogaleus* by the following combination of characters. The integument is rather thin and semitransparent. The second and third segments are coalesced together at least in the adults of both sexes. The posterior region of the female body from the fourth segment backward is not longer than the carapace. The dorsal plates of the fourth segment do not extend beyond the middle of the genital segment, and are circumscribed with recurved spines on all sides except the fore

margin. The claw of the second maxillipeds is bifurcate at the tip. The first three pairs of legs are furnished with natatory spines, which are doubly edged by hairs and not beset with multiserial ones as in other species. The male has a pair of rudimentary dorsal plates on the fourth segment and the elongate, styliform caudal rami. The exopodite of the fourth legs are three-segmented, and all the pairs of legs are armed with well-developed natatory spines.

It is noteworthy that the juvenile males described above are closely resembling in general body constitution to *Nogagus socialis* Olsson, about which the author states (1869) "*Echthrogaleus perspicaci* immixta". This latter species, however, is entirely distinct from the new species.

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Parasitic Copepods of the Eastern Pacific Fishes

4. On *Clavellistes shoyoae* gen. et sp. nov.

Sueo M. Shiino

(With Two Text-figures)

The members of the family Lernaeopodidae are usually attached to the host either on its gills, or on its body side. The new representative of the family to be described here is very interesting for its unusual location on the host body, such as around the eye. It shows, further, a certain new combination of characters of both the sexes on account of which it can not be assigned to any of the known genera. The new genus which will be proposed for the reception of this form is referred to the subfamily Clavellinae.

Genus *Clavellistes* gen. nov.

Female cephalothorax differentiated from trunk, elongated cylindrical, and in line with the latter, or flexed dorsally. Trunk swollen, without posterior process, abdomen and caudal rami, but with an unpaired genital process. First antennae four-segmented. Second antennae indistinctly bilobed, turned toward each other across the frontal margin of head. Maxillae ending in two well-developed and one rudimentary spines and carrying a palp with two apical spines. First maxillipeds removed far from other limbs and displaced as far forward as the posterior end of cephalothorax; members of both sides completely fused together into an ovoidal massive bulge with which the body is fastened to the host. Second maxillipeds chelate and placed in front of first maxillipeds and just behind the maxillae. Rest limbs absent. Egg tubes dorsal to genital processes, packed with multiserial spherical eggs.

Male body composed of cephalothorax and well-developed trunk. The latter makes a right angle with the former and has more or less distinct segmentation. First antennae filiform, three-segmented. Second antennae biramous, their endopodite two-segmented, ending in a curved claw. Maxillae as in the female. Two pairs of maxillipeds forming chelae. Trunk entirely devoid of appendages. Caudal rami present, short.

In the possession of an elongate cephalothorax, in the completeness of mutual coalescence of the first maxillipeds, in the absence of the posterior process of the trunk, and in the development of the genital process, the new genus is allied to *Clavella* Oken, *Clavellopsis* Wilson, *Clavellodes* Wilson, *Clavellisa* Wilson, *Anaclavella*

Heegaard and *Euclavellisa* Heegaard. It is distinguished from all of these for the first ground by the characteristic formation of the unpaired massive swelling originating in the fusion of the first maxillipeds. Besides, the present parasite can not be referred to any of those genera on account of the male characters. In all of those genera except *Anaclavella* and *Euclavellisa*, the males are ovoidal in shape having the trunk segments entirely undifferentiated, or strongly reduced. The male of *Euclavellisa* has a distinctly segmented trunk, which does not reach such a magnitude as that found in the new genus. In *Anaclavella* the male is unknown. The male of the new genus bears a certain resemblance in its constitution to the same sex of *Eubrachiella* Wilson, *Brachiella* Cuvier, and *Probrachiella* Wilson. In these genera, however, the first maxillipeds of the female are separated from each other at least for some distance from their bases, and the trunk carries the posterior processes. As the bulla was lost in all of the specimens in my hand, I was unable to make out anything about it.

Clavellistes shoyoae sp. nov.*

(Figs. 1–2)

Locality: The Pacific, 24°51.5′S, 103°16.0′W.

Date: January 22, 1963.

Collector: W. L. Klawe of the Inter-American Tropical Tuna Commission. Collection was made when he was aboard "Shoyo Maru", the survey ship of the Ministry of Agriculture and Forestry of Japanese Government, in her twelfth cruise.

Host: *Lampris regius* (Bonnaterre). External, around the eye.

Specimens: Five females and one male. The female carrying the male was made the holotype. One female was without arm, and another with arm broken. Of these, the former was used for dissection.

Coloration: The cephalothorax of the female white in formalin, the genital segment and egg tubes light yellow. Male whitish.

Measurements: Female No. 1 (holotype, Fig. 1A): Entire length 3.31 mm, the cephalothorax 1.54 mm × 0.39 mm, the trunk 1.46 mm × 1.08 mm, the arm 1.00 mm × 0.92 mm, the genital process 0.31 mm × 0.31 mm, the egg tube 1.92 mm × 0.39 mm. Female No. 2: Entire length 3.47 mm, the cephalothorax 1.46 mm × 0.39 mm, the trunk 1.62 mm × 1.00 mm, the arm 1.08 mm × 0.93 mm, the genital process 0.39 mm × 0.31 mm, the egg tube 1.24 mm × 0.46 mm. Female No. 3: Entire length 3.15 mm, the cephalothorax 1.46 mm × 0.39 mm, the trunk 1.46 mm × 1.00 mm, the arm 1.00 mm × 0.92 mm, the genital process 0.23 mm × 0.23 mm, the egg tube 2.16 mm × 0.54 mm. Male (allotype, Fig. 2A): 0.93 mm long, the carapace 0.69 mm long, 0.49 mm thick, the trunk 1.64 mm long, 0.26 mm wide.

Female: The external cuticle is detached from the non-chitinous part of body

* After the suggestion of Dr. W. L. Klawe, I have associated this species with the name of "Shoyo Maru".

by the intervention of a narrow space. It is rather thin, at times more or less rugose, and especially so on the ventral side of the trunk.

The cephalothorax is elongate, occupying about a half of the entire length. It is cylindrical, bent dorsally, or in line with the trunk and strongly flexible. The carapace is distinct, longer than wide, and quadrangular in dorsal aspect having truncate fore margin. Cephalic and post-cephalic appendages are crowded together on the ventral surface of the carapace excepting the first maxillipeds (the arm), which are far removed from others and displaced to the cephalothoracic end.

The trunk is about one and a half times as long as wide and nearly quadrate in shape. It has parallel, even sides, which are incurvated at the fore end making shoulders and are slightly notched a little in front of the middle. The ventral surface is, at times, traversed by series of transverse rugae continuing to the deep lateral constrictions which are ordinarily obsolete. The caudal end of the trunk is wanting in any accessory prolongations, but has inconspicuous lateral bulges which are bordered from the median region by deep incisions. The genital process is a little shorter than a quarter of the trunk, obovate, and is attached to the caudal end of the latter on the level with the ventral surface. The egg tubes are subequal to the trunk in length and packed with multiserial spherical eggs.

The first antennae are four-segmented, filiform and located on either side of the mouth tube. The apical segment is more or less indistinctly bordered from the next basal and ends in two spines. The basal segment is enlarged. The second antennae are thick, fleshy, indistinctly bilobed appendages which are located outside the other limbs. The members of both sides are turned down across the fore end of the carapace, their apices overlapping each other. The outer ramus is a simply round lamella and covers the underlying smaller inner ramus which is tipped by two short spinules. The mandibles enclosed within the mouth tube have the blade cut into seven blunt incurvated denticles. The maxillae terminate in two subequal acuminating spines, which are accompanied on the outside by a very tiny spinule. The small palp is tipped by two short spinules. The second maxillipeds are close behind the maxillae, subchelate in structure. The palm is oblong ovate and bears a tiny spine on the inner border internally to the point against which the tip of the claw acts; the claw reaches the middle of the palm, ending in a sharp spine which is associated at the base with an inner accessory spinule. The first maxillipeds of both sides are entirely fused from the very base into a massive ovoidal protuberance, which is attached to the base of the cephalothorax. The protuberance is about two thirds as long as the trunk and only slightly narrower than its own length. No bulla was retained at the top of the protuberance in any of the specimens.

Male: The male is attached to the female body by the aid of two pairs of prehensile maxillipeds. The body is large as compared with the size of the female, and is distinctly divided into the carapace and the trunk, both making a right angle with each other. The external cuticle is rugose on the surface and detached from

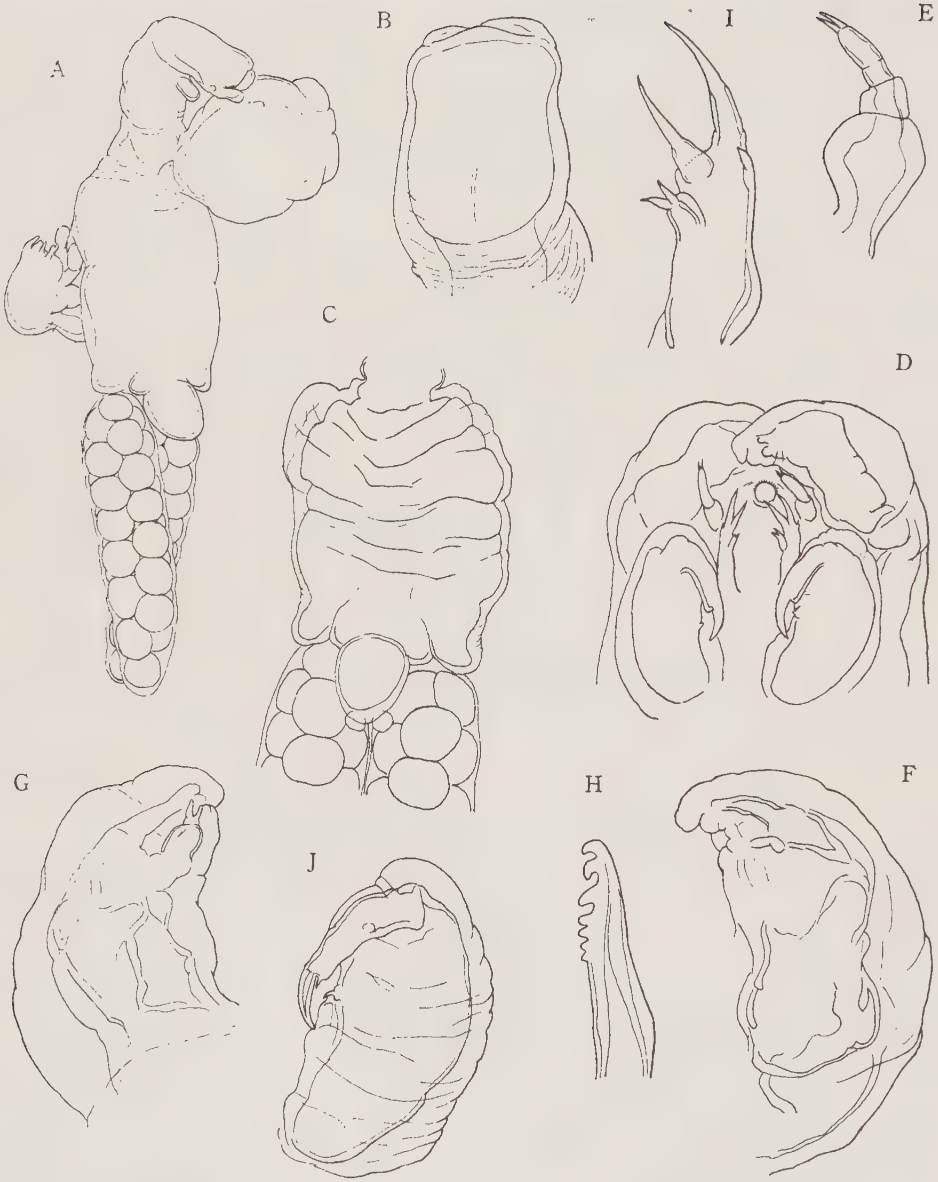

Fig. 1. *Clavellistes shoyoae* gen. et sp. nov.

A, female, holotype, with male; B–J, female, paratype; B, carapace, dorsal aspect; trunk, ventral aspect; D, head, ventral aspect; E, first antenna; F, second antenna; G, same, inner side; H, mandible; I, maxilla; J, second maxilliped. A ×21; B ×46; C ×30; D ×93; E–G, J ×183; H ×670; I ×380.

the body, a considerable space intervening between them especially in the trunk.

The carapace is oblong ovate in dorsal aspect, and produced in front into a small crescentic lobe. The trunk is attached to the ventral surface of the carapace

a short distance in front of the posterior angle. It is much narrower than the carapace, cylindrical, and consists of four segments. The caudal rami are placed at the hind end on a level with the ventral surface and are composed of ovoidal base and narrower apex.

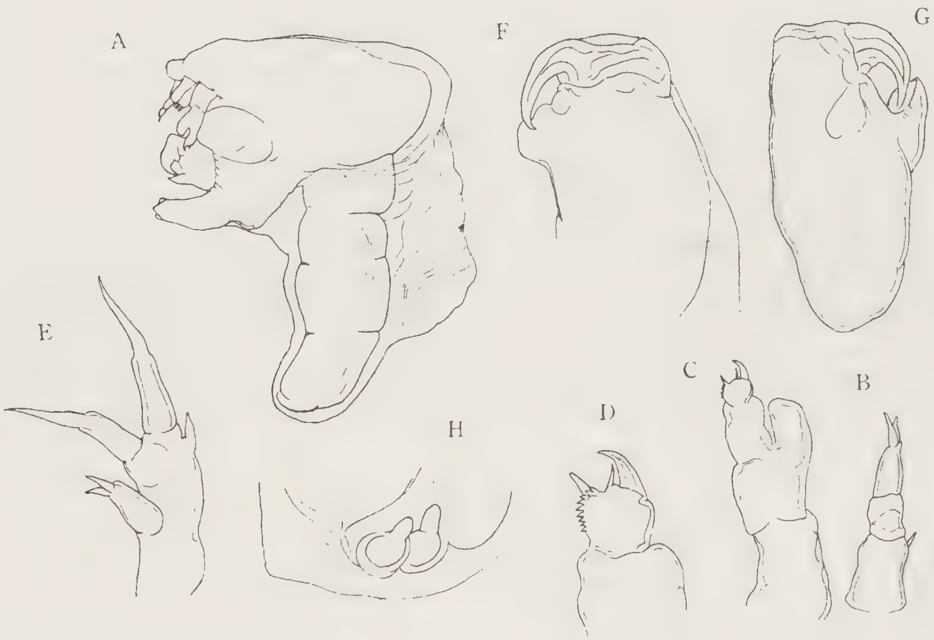

Fig. 2. *Clavellistes shoyoae* gen. et sp. nov.
A, male, allotype, lateral aspect; B, first antenna; C, second antenna; D, endopodite of same; E, maxilla; F, first maxilliped; G, second maxilliped; H, caudal rami. A ×58; B, C ×230; D ×545; E ×380; F-H ×190.

The first antennae are three-segmented, and armed with two short spines on the apical segment and with another spine on the basal segment. The second antennae are bifurcated. The endopodite is two-segmented; the apical segment possesses a sharp, strong, incurvated claw at the outer distal angle and two much feebler, simple spines internally to this, and is serrated on the inner border. The exopodite is a simple, quadrate lobe which is shorter than the endopodite and without any armature. The maxillae are similar to those of the female in structure. The first and second pairs of maxillipeds are chelate. The palm of the first pair forms at the inner distal angle a low bulge, against which the sharp, curved claw acts. The second pair are somewhat slenderer but longer than the first pair. The palm of the second pair is elongate oval and bears a triangular process, into whose inner depression it receives the sharp apex of the stout, strongly curved claw; the process is circumscribed by tubercles around the circumference of the inner sur-

face. Other appendages are missing.

Remarks: The vial containing the specimens was furnished with description no more than "around the eye." I am not certain whether they attach themselves to the corneal surface as *Ommatokoita superba* Leigh-Sharpe does. At any rate, this species is distinct from the new species in the extreme shortness of the female cephalothorax as well as in the elongation and separation of the first maxillipeds of the two sides. The new species bears a certain resemblance to *Cauloxenus stygius* Cope which was described from the lips of *Amblyopsis spelaeus* in the general appearance of the body. This species, which is unaccompanied with the male, has never been adequately defined. But the absence of the genital process may be sufficient to distinguish this species from the new one.

T. Scott and A. Scott recorded from the gills of *Lampris pelagicus* in Shetland a parasite under the name of *Lernaeopoda lampri*. They maintained this form to be a male and assigned to the genus *Lernaeopoda* with reservation that this bears a relationship "closer perhaps with *Charopinus* than with *Lernaeopoda*". Judging from the figure given by them, however, it appears to me there is a probability that their specimen might represent a juvenile female stage. It is said that this measures 4.3 mm, a length even larger than that of the largest female of the present species.

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On Some Notodelphyoid Copepods from the Bay of Kesennuma

Shigeko Ooishi

The bay of Kesennuma located in Miyagi Prefecture, Japan, has many of oyster beds on its bosom. These beds inhabited also by a vast number of simple ascidians in natural state are used by the people for culturing edible ascidians. In the last decade of August, 1962, the author was able to obtain some Notodelphyoid Copepods in the ascidians growing on these beds. The specific names of the copepods and their hosts are listed in Table 1. The species obtained were four in all. Of these, *Pachypygus gibber* and *Notodelphys agilis villosus* have been described by the author from other regions of Japan (Ooishi, 1961 & 1962). The rest two, belonging to *Bonnierilla* and *Doropygus* respectively, were apparently new to science, and are here dealt with. *Bonnierilla* living in the pharynx of *Halocynthia*, an edible simple ascidian, is harmless to human beings. In addition to the hosts shown in Table 1 two other species of simple ascidians, *Styela clava* Herdman (224 specimens) and *Corella japonica* Herdman (80 specimens), could be collected from the oyster beds and by the dredgings. They had no Notodelphyoids in their interior.

Table 1. Frequency of occurrence of Notodelphyoid Copepods in their host ascidians in the Bay of Kesennuma.

Notodelphyoid copepods		Ascidians	
species names	number obtained	species names	number examined
Bonnierilla curvicaudata n. sp.	55♀+5♂	*Halocynthia roretzi* (von Drasche)	8
Doropygus elegans n. sp.	52♀	*Ciona intestinalis* (Linnaeus)	550
Pachypygus gibber (Thorell)	10♀		
Notodelphys agilis villosus (Thorell)	3♀	*Ascidia zara* Oka	67

Before going further, I wish to express my hearty thanks to Mr. C. Nakamura, Head of Kesennuma Branch of Miyagi Prefectural Fisheries Experimental Station, for his kindness in facilitating the collection of the materials. Author's thanks are also due to Mr. H. Onodera, Dr. S. Sakai and Mr. I. Terasawa, who are the members of that Branch, for their cooperation in collecting greater part of ascidians.

Fig. 1, *Bonnierilla curvicaudata* n. sp., female. A, lateral view; B, urosome, ventral view; C, antennule; D, antenna; E, mandible; F, maxillule; G, maxilla; H, maxilliped. A × 35; B × 65; C × 100; D × 185; E, F, G, H × 270.

Bonnierilla curvicaudata n. sp.

Female: Yellowish brown and similar in color to the host branchial sac. Body (Fig. 1, A) much compressed, 2 mm long from the anteriormost of prosome to the end of urosome. Prosomic shield with blunt, laterally flaring epimera and fused posteiorly with metasome. Rostrum produced into a semicircular lobe between antennular bases of both sides. First legs issued from prosome. Much-inflated metasome comprises 3 poorly defined leg-bearing segments. Brood sac occupies entire metasome, extending from the segment of 2nd legs to that of 4th legs; in gravid female it is vaulted both in front and in the rear as well as dorsally. Articulation of metasome to urosome falls between 4th and 5th leg-bearing segments. Urosome (Fig. 1, B) is 5-segmented inclusive of 5th thoracic segment and perianal ring, which bears caudal rami. Genital aperture lies on anterior edge of 2nd urosomal segment. Caudal ramus is about 1/3.5 times as long as urosme.

Antennule (Fig. 1, C) 8-jointed, short and reaching the middle of prosome. Setal formula: I, 4; II, 15+1 hook; III, 9 & 1 aesthetask; IV, 5 & 1 aesthetask; V, 1; VI, 2; VII, 3; VIII, 7+1 aesthetask.

Antenna (Fig. 1, D) 3-jointed. Proportions of joints from the 1st to the last as 1: 1/2: 2/3. First joint with a setule at inner distal corner. Second joint with a short seta at the distal fifth of outer margin. Third joint carries a group of 3 minute setae at the distal quarter of outer margin, a similar one at the proximal third, and terminates in a stout curved hook associated with 5 short setae.

Mandible (Fig. 1, E) consists of 2-jointed protopodite, 2-jointed endopod and 1-jointed exopod. Inner border of coxa is cut into 4 heavy teeth followed by a row of tiny ones and 2 proximal setules; 3rd tooth bears a few spinules on its distal side. Basis is broad, with a single inner seta near the end. First endopod joint is fringed with 4 setae graded in lengths on inner border. Second joint is armed with 9 setae circumscribing inner and terminal margins. Exopod bears 3 integumentary folds and 5 rather long, stout setae.

Maxillule (Fig. 1, F) has 2-jointed protopodite and 1-jointed rami. Outer distal angle of coxa carries an epipodite in the form of a stout seta and a setule, and inner margin bears 2 expansions representing endites. Proximal endite is rimmed with 9 setae of varying size along inner margin; distal endite has a smaller outgrowth resembling a seta. Basis is furnished with 3 subequal setae on distal margin. Endopod has 4 marginal setae. Exopod is larger, with 4 subequal setae.

Maxilla (Fig. 1, G) 5-jointed, broad at the base, attenuating toward the tip. Basal joint occupying more than half of entire length and issuing 4 endites; 1st endite with 3 setae, 2nd with 1, 3rd with 2, and 4th with 2 as well as with a tiny accessory setule. Second joint is wider than long, and produced medially into a stout, elongate claw, from whose base a long seta and a short setule arise. Each of succeeding 2 joints has a long seta at inner distal angle. Fifth joint bears 3 terminal setae.

Maxilliped (Fig. 1, H) uniramous, showing an integumentary fold between terminal lobe and basal portion. Basal portion armed on inner margin with 9 setae

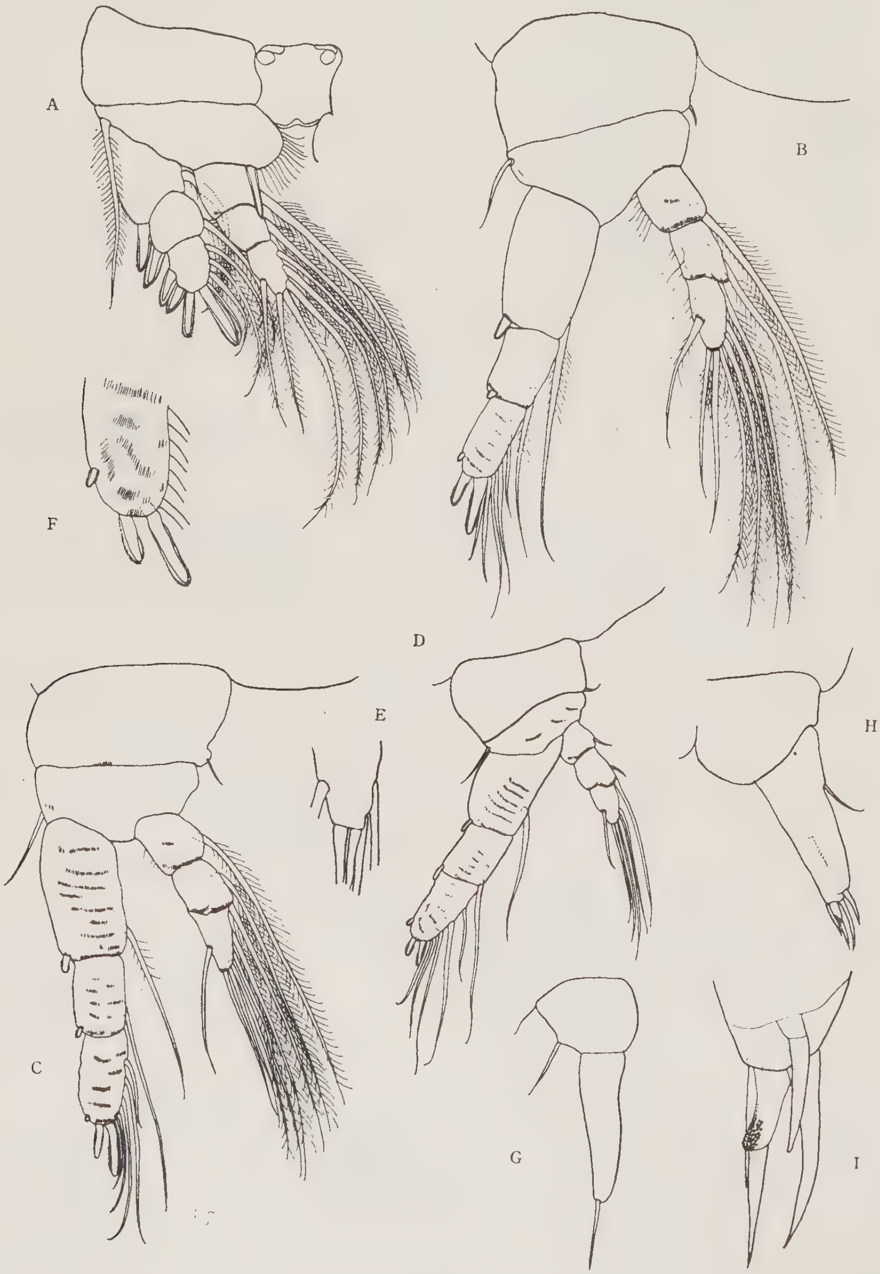

Fig. 2, *Bonnierilla curvicaudata* n. sp., female. A, 1st leg; B, 2nd leg; C, 3rd leg; D, 4th leg; E, endopod apex of same; F, exopod apex of same; G, 5th leg; H, caudal ramus; I, apex of caudal ramus. A, B, C, D × 185; E, F × 270; G, H × 140; I × 340.

dividing into distal group of 5 and proximal one of 4. Terminal lobe tipped by 2 setae and hairs on inner margin.

First swimming leg (Fig. 2, A) composed of 2-jointed protopodite and 3-jointed rami. Protopodites of both sides connected together by a broad subtriangular intercoxal plate. Coxal armature lacking. Basis has a stout tapering spine at inner-distal corner and a long plumose seta on outer margin. Endopod is slightly shorter than exopod, and has 8 setae, which are disposed 1 on inner border of each of basal 2 joints, 3 on the same border, 2 at the apex and 1 on outer border of terminal joint. Exopod is furnished with 6 spines and 6 setae; precisely, an outer spine and inner seta on first 2 joints, 3 outer and 1 apical spines as well as 4 inner setae on 3rd joint. All the setae are plumose in nature.

Second swimming leg (Fig. 2, B) with 2-jointed protopodite and 3-jointed rami of unequal length. Intercoxal plate reduced. Coxa with a tiny setule at inner distal corner. Basis with a short simple outer seta, reaching the middle of 1st exopod joint. Endopod far smaller than and 2/3 as long as exopod, and carrying 9 plumose setae in all. First joint armed with 1 inner seta, 2nd with 2 inner setae, and 3rd with 3 inner, 2 apical and 1 outer setae. Inner setae are all displaced to posterior surface, owing to the twisting of the ramus around its axis. Exopod provided with 7 setae and 5 spines. First joint wider and longer than either of rest joints, and carrying 1 short thick spine at outer distal corner and 1 long plumose seta at a distal quarter of inner margin. Second joint similar to the 1st in armatures. Third joint has 1 outer vestigial spine and 2 apical well-developed ones, 1 apical and 4 inner setae, which are much feebler and non-hairy.

Third swimming leg (Fig. 2, C) has protopodite and rami very similar to those of the preceding.

Fourth swimming (Fig. 2, D, E, F) relatively smaller than the first 3 legs. Endopod less than half as long as exopod, and carrying 8 non-hairy setae. Basal joint with a very short inner seta, middle joint with a similar one at its distal third and 1 long inner seta at the extreme end, and terminal joint (Fig. 2, E) with 2 inner, 2 apical and 1 outer rather long setae. Exopod furnished with 5 spines and 7 setae as the preceding legs.

Fifth leg (Fig. 2, G) 2-jointed. Basal joint half as long as terminal joint; the former with a short slender seta at outer distal angle and the latter ending in a similar one.

Caudal ramus (Fig. 2, H, I) only slightly curved, conical, with truncate end, and 2.2 times as long as the greatest width. It carries 3 stout terminal setae of varying size, 1 blunt spine with several apical rows of fine tubercles, and a ventral seta present a little proximad to these. Besides these, there are 2 short setae, one on dorsal face at a point two-fifths behind the apex and the other on outer side at the basal one-third.

Male: Body (Fig. 3, A) taperig posteriorly and distinctly differentiated into prosome, metasome and urosome, with proportional lengths as 6: 7: 8 in due order.

Fig. 3, *Bonnierilla curvicaudata* n. sp., male. A, lateral view; B, urosome, ventral view; C, antennule; D, antenna; E, mandible; F, maxillule; G, maxilla; H, maxilliped. A × 100; B × 140; C × 270; D, E, G × 400; F, H × 530.

Length from the top of prosome to the end of caudal rami 0.8 mm. Metasome 4-segmented, with segment of 1st legs indicated only on dorsal side. Boundary of metasome and urosome lying between 5th (bearing 4th legs) and 6th (bearing 5th legs) thoracic segments. Urosome (Fig. 3, B) 6-segmented, somewhat attenuating backward. Caudal ramus about twice as long as anal segment. Rostrum (Fig. 3, C) as in female.

Antennule (Fig. 3, C) 8-jointed as in female. Setal formnla is: I, 4; II, 16+1 hook; III, 6; IV, 7+1 aesthetask; V, 1+1 aesthetask; VI, 2; VII, 0; VIII, 5+1 aesthetask.

Antenna (Fig. 3, D) similar to that of female in contour and ornaments, except that setal number on 3rd joint is smaller by one and the same on 1st joint larger by one.

Mandible (Fig. 3, E) largely in accord with that of female in structure.

Maxillule (Fig. 3, F), maxilla (Fig. 3, G) and maxilliped (Fig. 3, H) substantially conforming to the corresponding limbs of female.

First swimming leg (Fig. 4, A) largely in agreement with that of female, but succeeding 3 (Fig. 4, B, C, D) differing from those of female in the armature and ornamentation on both the rami. Setae of endopod much shorter than in female, while spines and setae of exopod longer. Terminal joint of exopod of 2nd leg bearing an additional outer spine. Endopod of 4th leg (Fig. 4, E, F) has setae reduced, and carrying 6 setules, disposed one on 2nd joint and 5 on 3rd joint. Apical spinous processus of terminal endopod joint (Fig. 4, F) stouter than in female.

Structure of fifth leg (Fig. 4, G) resembling that of female. Basal joint indistinctly bordered from the body, somewhat longer than in female and with a transverse row of denticles at inner distal angle. Second joint has 3 similar rows on inner border.

Sixth leg (Fig. 4, H, I) present on 2nd urosomal segment carrying spermatophore, and triangular in outline. It bears 2 slender setae, one on outer margin and the other at the apex. Limb bases of two sides meet each other on the mid-ventral line.

Caudal ramus (Fig. 4, J) about 4 times as long as wide, 2.6 times as long as anal segment, and resembling that of female in essential characters. It is provided with a well-developed seta on dorsal side, with another similar seta on outer side and with 4 setae and 1 spine at the end, though outer and dorsal setae are longer than in female and the spine is without apical tubercles.

Remarks: This species is recognizable by its unusually inflated body, with flabelliform outline in lateral aspect. Another characteristic of the form may be found in the ornaments of caudal rami. The present form is nearly allied to *B. similis* Illg & Dadley in the structure and armatures in most of the appendages, but different in the constitution of the caudal rami. These of the female terminate in a blunt spine with many apical tubercles and in 4 short setae. This is the first record of the male in the genus *Bonnierilla*. Morphorogical features of its appendages

Fig. 4, *Bonnierilla curvicaudata* n. sp., male. A, 1st leg; B, 2nd leg; C, 3rd leg; D, 4th leg; E, endopod of same; F, 3rd endopod joint of same; G, 5th leg; H, 6th leg; I, same, lateral view; J, caudal ramus. A, B, C, D, G, H, I × 270; E × 450; F × 850; J × 400.

are in conformity with those of the female in the basic plan.

Doropygus elegans n. sp.

Female: Body (Fig. 5, A, B) compressed, 3.5 mm long from the top of prosome to the end of caudal rami, and divisible into prosome, metasome and urosome. Prosome unusually large, with well-developed tergum and carrying appendages up to maxilliped. Rostrum (Fig. 5, D) a semicircular lobe. Metasome composed of 4 limb-bearing segments; 4th segment inflated to form a marsupium. Marsupium relatively small for a species of *Doropvgus*, and containing large eggs. Articulation between metasome and ursome lying in front of 5th thoracic segment with reduced legs. Urosome (Fig. 5, C) composed of 6 segments with proportional lengths from 1st to last as 6: 5: 7: 6: 5: 4. Second segment with genital aparture near the anterior end.

Antennule (Fig. 5, E) 9-jointed, tapering distally, with basal 2 joints neither expanded nor elongated. Second joint accompanied at its base by a triangular setiferous lobe. Setal formula: I, 3; II, 17; III, 6; IV, 5; V, 4; VI, 4; VII, 2; VIII, 3; IX, 7+1 aesthetask. Longest setae on joints I, IV, V, VI and IX.

Antenna (Fig. 5, F, G) 3-jointed and slender. Proportions of joints from 1st to last as 5: 3: 3. First joint with 2 minute setae at the top of small process of inner distal angle. Second joint non-setose. Third joint with 3 short setae on outer face at the point 2/3 away from the base, with 2 curved rows of spinules on inner margin, and surmounted by a claw accompanied by 6 short setae of varying lengths.

Mandible (Fig. 5, H, I) composed of 2-jointed protopodite, 2-jointed endopod and 1-jointed exopod. Masticatory lamella of coxa marginated by 5 stouter anterior teeth, followed by serration and 2 posterior setules. Basis longer than wide, carrying a seta on inner margin. First endopod joint furnished on medio-distal border with a row of 4 setae graded in length. Second joint has 10 setae; of these, apical 3 are long and exceeding twice the length of others which are subequal. Exopod bears 5 long setae on inner and distal margins, distalmost of these being shorter and slenderer than others. All the setae are plumose.

Maxillule (Fig. 5, J) consists of 2-jointed protopodite and 1-jointed rami. Epipodite represented by a plumose seta associated just distally with a tiny setule. Proximal endite of coxa carrying 8 subequal setae and 2 tiny setules on inner border. Distal endite represented by a stout seta. Basis armed with 3 setae of graded lengths on inner margin. Both rami furnished with 3 subequal setae. Exopod has a tiny setule inserted between proximal 2 setae.

Maxilla (Fig. 5, K) narrow and 5-jointed. Basal joint longer than rest joints combined, and with 4 endites. First endite with 3 subequal setae, 2nd with 1, 3rd with 2, and 4th with a basal setule besides with 2 setae. Second joint about as wide as long, produced medially into a long spiniform process denticulated near the tip, and with 1 seta longer than this and accompanied by vestigial setule. Third

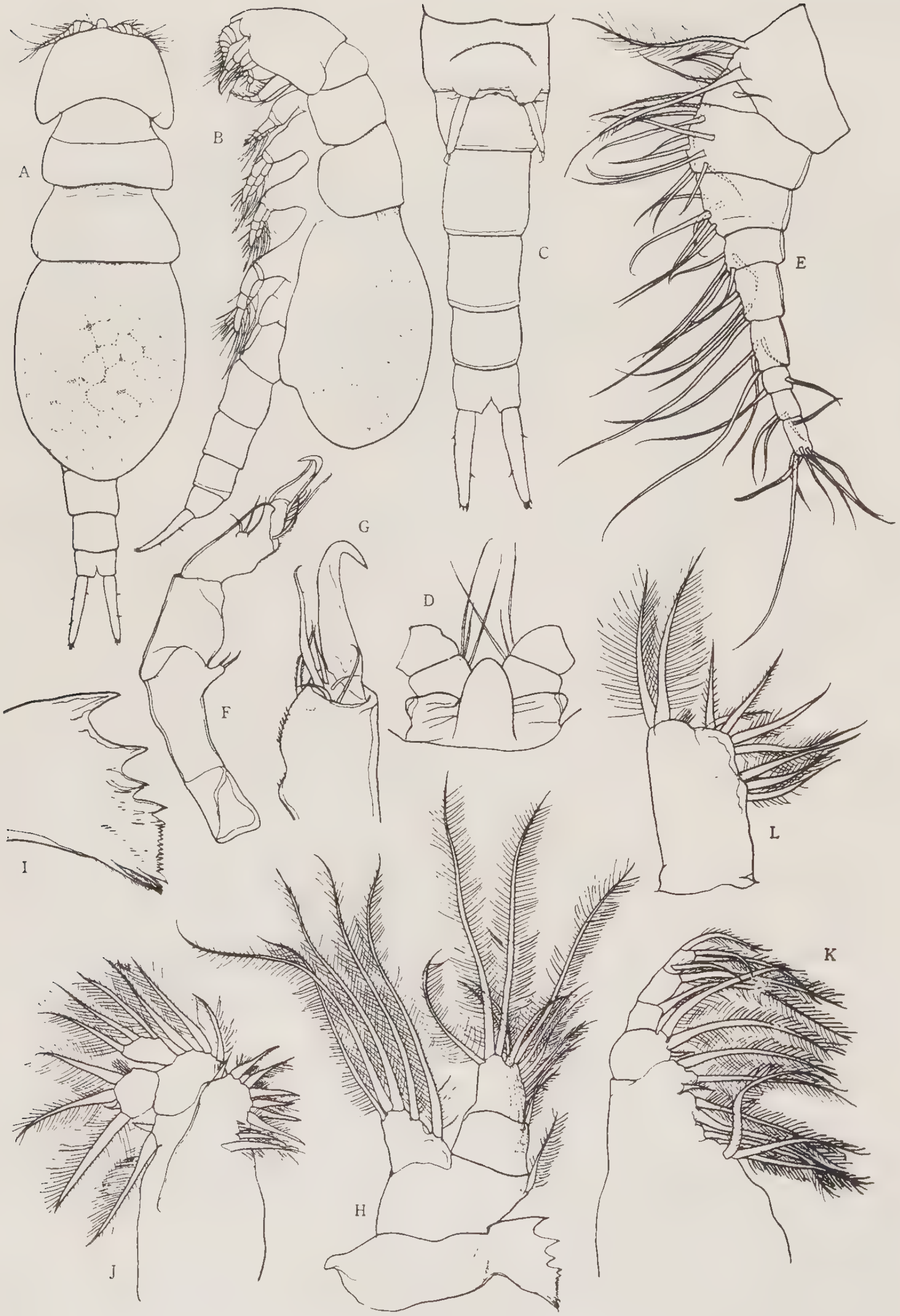

Fig. 5, *Doropygus elegans* n. sp., female. A, dorsal view; B, lateral view; C, urosome, ventral view; D, rostrum; E, antennule; F, antenna; G, apex of same; H, mandible; I, palp of same; J, maxillule; K, maxilla; L, maxilliped. A, B × 25; C × 35; D × 65; E, F × 140; G, I × 270; H × 100; J, K, L × 165.

and 4th joints bear each a single long seta. Terminal joint carries 4 short apical and inner setae.

Maxilliped (Fig. 5, L) unjointed. Setae on inner margin arranged in 2 groups; the distal group comprising 5 and the proximal 4. Coalesced terminal lobe bears 2 long subequal, distally directing setae and short hairs medially to these.

First swimming leg (Fig. 6, A) with 2-jointed protopodite and 3-jointed rami. Intercoxal plate subtriangular. Coxa bears at inner distal corner a seta, extending a little beyond 1st endopod joint. Basis has a long, stout, inner distal spine slightly surpassing 2nd endopod joint and a short outer seta. Endopod with 8 long setae. Basal 2 joints bearing each an inner seta. Third joint with 3 inner, 2 apical and 1 outer setae. Exopod with 6 spines and 6 setae; each of basal 2 joints with 1 large outer spine and 1 inner seta, and distal joint with 3 outer and 1 apical spines as well as 1 apical and 3 inner setae. All the spines with a tiny basal spinule.

Second swimming leg (Fig. 6, B) with 2-jointed protopodite, 2-jointed endopod and 3-jointed exopod. Intercoxal plate much reduced. Inner seta of coxa reaching the end of 1st endopod joint. Basis with a short outer seta. Endopod elongate, only slightly shorter than exopod and furnished with 9 long setae; basal joint occupying a quarter of entire length and with 1 seta on inner side; terminal joint formed by coalescence of 2 joints and armed with 5 inner, 2 apical and 1 outer setae. Exopod with 6 setiform spines and 7 setae. First 2 exopod joints each armed with 1 outer spine and 1 long inner seta. Apical joint with 3 outer and 1 apical spines and 1 apical and 4 inner setae. All the spines (Fig. 6, C) setiform and with a row of denticles along outer margin in its distal two-thirds.

Third swimming leg (Fig. 6, D) resembling 2nd leg in constitution except for the smallness of endopod in proportion to exopod.

Fourth swimming leg (Fig. 6, E) differs from 3rd in further advanced reduction of armature of endopod. Terminal joint of endopod has setae smaller in number than in 3rd by one. Seta of coxa and proximal setae of endopod and exopod are relatively shorter than the corresponding setae of 3rd. Endopod with 8 plumose setae and exopod with 7 plumose setae and 6 setiform spines.

Fifth leg (Fig. 6, F) 2-jointed; basal joints of both sides fused into one and the line of articulation to body more or less obliterated. Basal joint furnished with a short seta at outer distal corner. Second joint long, reaching the end of 2nd urosomal segment, and terminating in 2 reduced setae. Inner margin ornamented by 6 rows of very fine denticles.

Caudal ramus (Fig. 6, G, H) long, slightly tapering, about 5.5 times as long as greatest width and about twice as long as anal segment. It ends in 4 minute setae and bears a seta on outer border at about proximal one-third and another on dorsal face at about distal one-third.

Male: Unrepresented in the collection.

Remarks: The present species may be recognized by the relatively slender body and unusually large prosome. It is close to *D. laticornis* WILSON in the general

Fig. 6, *Doropygus elegans* n. sp., female. A, 1st leg; B, 2nd leg; C, spine of 1st exopod joint of same; D, 3rd leg; E, 4th leg; F, 5th leg; G, caudal ramus; H, apex of same. A, B, D, E, G ×100; C×400; F×140; H×340.

constitution and in the armature of appendages. Differences from this species may be found in the mandibular exopod and the terminal joint of maxilla being furnished with one additional seta, and in the maxillular exopod having a reduced seta beside 3 long setae. The body is yellowish in color when alive and the eggs are colored green to dark brown.

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Studies on the Marine Fouling Communities

II. Differences in the Development of the Test Block Communities with Reference to the Chronological Differences of Their Initiation

Tatuo KAWAHARA

(With Plates I–VIII)

In his previous work (I) the author devoted some discussion to the major changes in the development of the marine fouling community. For the purpose of constituting a certain contribution to our knowledge on the seasonal changes of fouling organisms in their attaching activity, he deals here with the divergence of the changes occurring during the development of a community with special reference to the difference of time when it is commenced.

The author desires to acknowledge his indebtedness to Prof. S. M. SHIINO for his kindness in reading over the manuscript.

1. Method

The experiments were carried on at Amakusa Marine Biological Laboratory, Kyūshū University in the early summer of 1944 and in the spring of 1946. For simplicity's sake those in the spring of 1946 will be called series A and the other series B. In both the series, the concrete blocks with length and width of 30 cm, and thickness of 2 cm were suspended from a raft launched at a point 50 m off the shore. They were maintained one meter below the surface, and were immersed one after another every 10 days and examined on the whole at an interval of 5 days. For further detail refer to the previous work (I).

Experiments of series A, the planning of which is shown in Fig. 1, were made ranging from January 31, 1946 to May 13 of the same year. Of ten test blocks of this series the one immersed first was treated in the previous paper with respect to the development of community. The series B which consists of immersion of five blocks extended from May 20 to July 9, 1944, and its planning is shown in Fig. 2. Fluctuation of water temperature during the two periods are added to the figures.

2. Succesive changes in each community

i. Experiment A.

Test block No. 1 (*date of immersion*: *January* 31). Development of the community

on this block has already been related for some detail in the previous article (KAWAHARA, 1962).

Test block No. 2 (*immersion on February* 10). On the 32nd day after immersion (March 13) the block was found slightly covered by minute algae and silt on its surface and carried a small amount of amphipod nests and hydroids on its marginal region. Couple of weeks afterwards (May 27) the surface grew brownish in colour owing to the growth of minute algae, and had *Spirorbis foraminosus* beginning to inclease in number, in addition to the hydroids which had invaded the central region of the surface. The community was thus in the beginning of Stage II (or the attaching period; KAWAHARA, 1962). Covered by silt, the growth of hydroids was declining on the 61st day (April 11), and they met destruction on the 75th day (April 25; Pl. I, Fig. 2). The community comprising 9 *Spirorbis*, 18 *Balanus trigonus* and a colony of *Watersipora cucullata* was thus in an early phase of Stage III (the growth period). On the 83rd day (May 3, Pl. II, Fig. 8), being in the middle phase of Stage III, it showed the decline of minute algae, but a conspicuous growth of

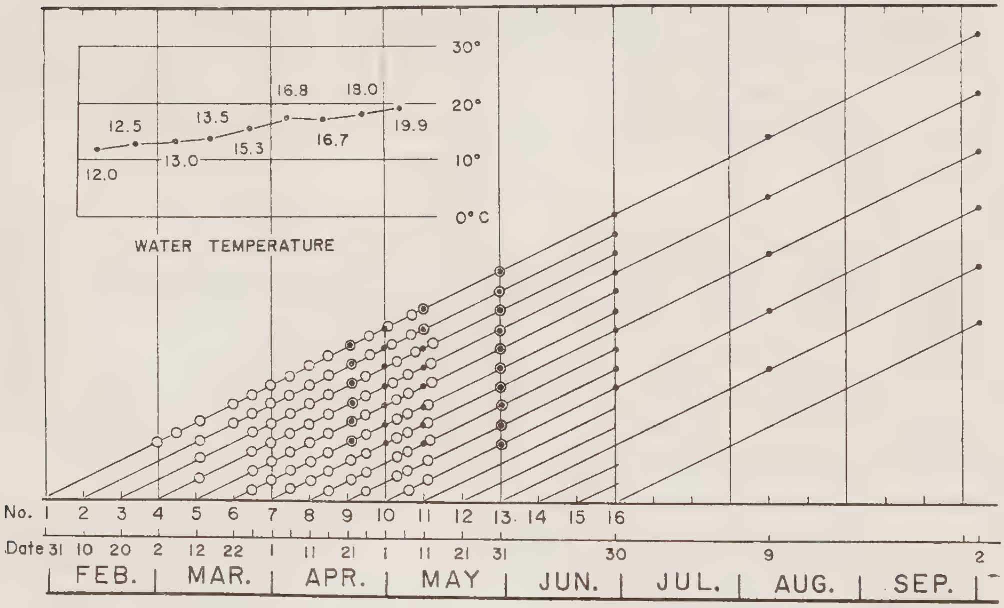

Fig. 1. Experimental plan of series A. Diagonal lines indicate the sequence of immersed test blocks, representing the days on which the measurement (○) and photograph (●) were taken. Temperature is represented by the mean during three decades of month.

barnacles. Eight days later (May 11, Pl. III, Fig. 15) small amphipod tubes had increased in their number and the "mat-like" growths of minute algae and nudibranchs both of which had been found were almost disappearing. The community contained, in addition, a colony of *Bugula neritina* and 25 individuals of *Styela plicata*. Prosperity of these and of *Leptoclinum mitsukurii* was observed on the 111th day (May

31; Pl. IV, Fig. 23), on which the community was in the last phase of Stage III. A month later (June 30; Pl. V, Fig. 33), the community, drawing near to the height of Stage IV (the flourishing period) showed perpetual growth of *Bugula* and *Styela.*

Test block No. 3 (*immersion on February* 20). On the 22nd day (March 13) a small number of amphipods made their appearance. In spite of the presence of microflora chiefly consisting of sessile diatoms and other minute algae, the block surface was still clean to the naked eye. On the 36th day (March 27), with the scattering settlement of hydroids and of six individuals of *Spirorbis foraminosus*, the community reached an early phase of Stage II. A half month later (April 11), the block surface was fouled by microflora carrying silt and by four *Balanus trigonus* and one *Bugula neritina.* Owing to vigorous growth of microflora and hydroids, on the block of the 62nd day (April 22; Pl. I, Fig. 3) it had become difficult to recognize new settlers. Abundance of nudibranchs and their spawns in the community was also worthy of note. Microflora and hydroids began to decline from the 74th day (May 4, Pl. II, Fig. 9) onwards in contrast to continuous growth of *Balanus*, to which nine *Styela plicata* were added. The community was in an early phase of Stage III. Drifting portions of the growing members had entirely dropped off on the 81st day (May 11; Pl. III, Fig. 16) though sessile animals continued their growth. The community was in the middle of Stage III. Reaching the advanced phase of Stage III, the community on the 101st day (May 31; Pl. IV, Fig. 24) comprised well-grown *Bugula* and *Styela*, and the green alga, *Enteromorpha sp.*, which was markedly increased in number. A month later (June 30; Pl. V, Fig. 34), with further growth of *Bugula* and *Styela*, the community was almost attaining to Stage IV.

Test block No. 4 (*immersion on March* 2). The block of the 11 days (March 13) after immersion was stainless on its surface except for a slight deposition of silt and fouling of the hanging ropes by a few amphipod tubes. On the 26th day (March 27) the surface had been stained light greenish brown by microflora and had a single individual of *Spirorbis foraminosus*, the community thus arriving at an early phase of Stage II. The block of the 41st day (April 11) was carrying hydroids in the marginal region, but a greater part of its surface was still destitute of any macrofouling. On the 52nd day (April 22; Pl. I, Fig. 4), microflora and hydroids covered by silt were increasing in their numbers and volumes, exhibiting "mat-like" growths. On the 63rd day (May 3; Pl. II, Fig. 10) they had again increased in their number and had more serious silt on them, and attachment of one *Bugula neritina* and 32 *Balanus trigonus* was discovered. On the 71st day (May 11; Pl. III, Fig. 17), hydroids and the "mat-like" growths were on the decline, and showing attachment of eleven individuals of *Styela plicata* and marked growth of *Balanus*, the community had reached an early phase of Stage III. Twenty days later (May 31; Pl. IV, Fig. 25), this had *Leptoclinum mitsukurii* in the central region of the block surface and vigorously growing *Bugula*. Another 20 days later (June 30; Pl. V, Fig. 35), the community was near the height of Stage IV, showing extreme development of *Bugula* and *Styela*. *Bugula* had lost vigour until the 161st day (August 9; Pl. VI,

Fig. 43) leaving some corpses which entirely disappeared before the 215th day (October 2; Pl. VII, Fig. 48).

Test block No. 5 (*immersion on March* 12). 15 days after initiation (March 27), being in an early phase of Stage II, the community was composed of a small amount of microflora and hydroids and a single individual of *Spirorbis foraminosus*. On the 31st day (April 11), the block surface was greenish brown in colour owing to the fouling by microflora, and had hydroids gradually increasing in number and volume. These latter had been greatly multiplied on the 42nd day (April 22; Pl. I, Fig. 5), inserting two individuals of *Balanus trigonus* amidst of them, and thus the surface growths were "mat-like" in its appearance. Decline of hydroids and microflora began from the 54th day on (May 4; Pl. II, Fig. 11), but spawns of nudibranchs and amphipod tubes found in earlier stages were still retained on the surface. With conspicuous growth of *Balanus* the community was thought to have reached an early phase of Stage III. After a week (May 11; Pl. III, Fig. 18) "mat-like" growths nearly went out of sight and *Leptoclinum mitsukurii* and *Balanus* were attaching and growing in turn. An elapse of 20 days (May 31; Pl. IV, Fig. 26) resulted in the marked growth of *Leptoclinum* and *Bugula neritina* and that of another month (June 30; Pl. V, Fig. 36) brought about the prosperity of *Bugula* and *Styela* which was a sign of approximate attainment to the height of Stage IV.

Test block No. 6 (*immersion on March* 22). 10 days after immersion (April 1), attachment of microflora began to be observed, despite the cleanliness of the block surface. On the 21st day (April 11), the surface covered by microflora was stained somewhat greenish brown and showed hydroids attaching a little by little. On the dirty surface of the 32nd day (April 22; Pl. I, Fig. 6), to which four *Spirorbis foraminosus* and one *Balanus trigonus* were newly attached, hydroids were gradually increasing in their number together with amphipods, and the community had attained to Stage II. Heavy fouling by microflora, hydroids and amphipod tubes, and increase in the number of nudibranchs and their spawns were the events notable on the 44th day (May 4; Pl. II, Fig. 12). In addition to them, one colony of *Bugula neritina* was found anew. Hydroids and "mat-like" growths were extinct on the 52nd day (May 12; Pl. III, Fig. 19). To a lot of amphipod tubes left on the surface three individuals of *Styela plicata* had been added. The community was in Stage III. Notwithstanding the smallness of their numbers, *Bugula* and *Styela* were growing larger in size on the 71st day (May 31; Pl. IV, Fig. 27), and benthos were multiplying in number as well as in species. A month afterwards (June 30; Pl. V, Fig. 37), with excessive growth of *Bugula* and *Styela* the community was almost in the height of Stage IV.

Test block No. 7 (*immersion on April* 1). Until the 11th day after initiation of experiment (April 11), only a small amount of silt was observable on the quite clean surface, the centre of which was inhabited by one individual of *Balanus trigonus*. The surface began to be covered by microflora from the 16th day (April 16) and showed a small colony of hydroids and two additional *Balanus*. The community

Table 1.

Experiment A. Changes in the number of animals occurring on the ten test blocks in their central regions (20cm × 20cm). + : occurrence in the rest region. Days: days elapsed after the commencement of experiment.

No. 2

Date	MARCH		APRIL						MAY		
	22	27	1	6	11	16	22	27	3	8	11
Days	40	45	50	55	60	65	71	76	82	87	90
Spirorbis foraminosus	1	6	9	8	8	9	9	9	8	8	8
Balanus trigonus	0	0	0	1	11	13	15	18	87	114	129
Balanus tintinnabulum rosa	0	0	0	0	0	0	0	+	1	2	3
Bugula neritina	0	0	+	+	0	0	0	+	+	+	1
Bugula californica	0	0	0	0	0	0	1	0	0	0	0
Watersipora cucullata	0	0	0	0	0	0	1	1	1	1	1
Styela plicata	0	0	0	0	0	0	0	0	0	7	25
Total	1	6	9	9	19	22	26	28	97	132	167

No. 3

Date	MARCH		APRIL						MAY		
		27	1	6	11	16	22	26	4	9	13
Days		35	40	45	50	55	61	65	73	78	82
Spirorbis foraminosus		6	8	8	8	9	11	13	14	14	14
Hydroides norvegica		0	0	0	0	0	0	0	0	0	1
Balanus trigonus		0	0	0	4	6	6	8	49	77	79
Bugula neritina		0	0	1	1	1	2	1	2	2	2
Bugula californica		0	0	0	0	0	0	0	1	1	1
Watersipora cucullata		0	0	0	0	0	0	0	0	+	+
Lichenopora radiata		0	0	0	0	0	0	0	+	+	+
Styela plicata		0	0	0	0	0	0	0	9	23	27
Leptoclinum mitsukurii		0	0	0	0	0	0	0	+	+	+
Total		6	8	9	13	16	19	22	75	117	124

No. 4

Date	MARCH		APRIL						MAY		
		27	1	6	11	16	22	26	3	7	13
Days		25	30	35	40	45	51	55	62	66	72
Spirorbis foraminosus		1	1	3	3	2	4	5	7	9	9
Hydroides norvegica		0	0	0	0	0	0	0	1	1	1
Balanus trigonus		0	+	+	+	+	+	2	32	67	84
Balanus tintinnabulum rosa		0	0	0	0	0	0	0	1	2	2
Bugula neritina		0	0	0	0	1	0	0	1	2	3
Watersipora cucullata		0	0	0	0	0	0	0	0	0	1
Styela plicata		0	0	0	0	0	0	0	0	1	11
Total		1	1	3	3	3	4	7	42	82	111

Table 1 cnotinued

No. 5

Date	MARCH		APRIL						MAY		
		27	1	6	11	16	22	26	4	7	13
Days		15	20	25	30	35	41	45	53	56	62
Spirorbis foraminosus		1	2	5	5	5	6	7	7	8	7
Hydroides norvegica		0	0	0	0	0	0	0	3	2	2
Balanus trigonus		0	0	0	1	2	2	4	31	77	94
Balanus tintinnabulum rosa		0	0	0	0	0	0	0	1	3	3
Bugula neritina		0	0	0	0	0	0	+	+	+	+
Bugula californica		0	0	0	0	0	0	0	0	1	1
Watersipora cucullata		0	0	0	0	0	0	0	0	2	2
Styela plicata		0	0	0	0	0	0	0	0	0	3
Leptoclinum mitsukurii		0	0	0	0	0	0	0	0	2	3
Total		1	2	5	6	7	8	11	42	95	115

No. 6

Date	MARCH		APRIL						MAY		
	22	27	1	6	11	16	22	26	4	7	12
Days	0	5	10	15	20	25	31	35	43	46	51
Spirorbis foraminosus		0	0	0	0	1	4	4	6	6	7
Hydroides norvegica		0	0	0	0	0	0	0	2	2	3
Balanus trigonus		0	0	0	0	1	1	4	16	51	66
Balanus tintinnabulum rosa		0	0	0	0	0	0	0	0	0	1
Bugula neritina		0	0	0	0	0	0	0	1	1	1
Lichenopora radiata		0	0	0	0	0	0	0	0	1	1
Styela plicata		0	0	0	0	0	0	0	0	0	3
Total		0	0	0	0	2	5	8	25	61	82

No. 7

Date			APRIL						MAY		
			1	6	11	16	22	26	4	7	12
Days			0	5	10	15	21	25	33	36	41
Spirorbis foraminosus				0	0	+	+	1	2	2	2
Hydroides norvegica				0	0	0	0	0	1	1	1
Balanus trigonus				0	1	3	4	4	10	21	42
Balanus tintinnabulum rosa				0	0	0	0	0	1	2	4
Bugula neritina				0	0	0	0	0	0	0	+
Leptoclinum mitsukurii				0	0	0	0	0	0	0	+
Total				0	1	3	4	5	14	26	49

Table 1 contiuned

No. 8

Date						APRIL				MAY	
					11	16	21	26	4	7	12
Days					0	5	11	15	23	26	31
Spirorbis foraminosus						0	0	0	0	4	11
Balanus trigonus						0	0	0	12	31	40
Balanus tintinnabulum rosa						0	0	0	0	0	+
Bugula neritina						0	0	0	2	2	2
Leptoclinum mitsukurii						0	0	0	0	0	+
Total						0	0	0	14	37	53

No. 9

Date						APRIL				MAY	
							21	26	4	7	12
Days							0	5	13	16	21
Spirorbis foraminosus								0	1	1	5
Balanus trigonus								0	6	23	26
Balanus tintinnabulum rosa								0	0	1	2
Leptoclinum mitsukurii								0	0	1	1
Total								0	7	26	34

No. 10

Date										MAY	
									1	7	12
Days									0	6	11
Spirorbis foraminosus										0	0
Balanus trigonus										0	0
Total										0	0

reached thus an early phase of Stage II. The surface of the 34th day (May 4; Pl. II, Fig. 13) was stained yellowish brown and fouled by hydroids and amphipod tubes invading the central region. After a week (May 11, Pl. III, Fig. 20), withering of hydroids was commenced contrary to the conspicuous growth of preexisting *Balanus*. Twenty days later (May 31; Pl. IV, Fig. 28) hydroids were found completely disappeared from the surface. With vigorous growth of *Leptoclinum*, *Bugula neritina* and *Styela plicata* the community had arrived in the last phase of Stage III. With one month's elapse (June 30; Pl. V, Fig. 38), during which full growth of

Bugula and *Styela* took place, the community was near the height of Stage IV. Another elapse of 40 days (August 9; Pl. VI, Fig. 44) resulted in the decline of *Bugula* leaving full-grown *Styela* behind. On the 185th day (October 2; Pl. VII, Fig. 49), by the decay of almost all the individuals of *Styela* original surface of the substratum was found again exposed extending in a large area.

Test block No. 8 (*immersion on April* 11). Only a small amount of microflora was observable on the surface on the 12th day (April 21). Although these as well as silt were still small in amount even after another lapse of the same length of time (May 4), hydroids and amphipod tubes made their appearance here and there and twelve *Balanus trigonus* and two *Bugula neritina* were found in the central region. Withering of hydroids began from the 32nd day (May 12; Pl. III, Fig. 21) onwards, whereas the growth of *Balanus* became noticeable. The community was thus in an early phase of Stage III. The events having taken place during the following 19 days (May 31; Pl. IV, Fig. 29) were the disappearance of hydroids, leaving many amphipod tubes, and the change of the surface colour into greenish tone resulted from the growth of microflora associated with *Enteromorpha*. *Bugula* and *Leptoclinum mitsukurii* were also remarkable in their growth. One month later (June 30; Pl. V, Fig. 39) the block was found fouled by full-grown *Bugula* and *Styela plicata*, though their numbers were not so large. The community was thus reaching early phase of Stage IV.

Test block No. 9 (*immersion on April* 21). Fortnight after initiation (May 4), the surface still clean was scattered here and there by small yellowish patches, and its central region was fouled by a small amount of hydroids and amphipods, by six *Balanus trigonus* and by one *Spirorbis foraminosus*. The surface of the 22nd day (May 12) was fouled by a lot of amphipod tubes and hydroids, both with silt and intermingled with abundant nudibranchs and their spawns. *Balanus* was marked in its growth. Hydroids and nudibranchs had disappeared on the 41st day (May 31; Pl. IV, Fig. 30). Until then, however, *Enteromorpha* had grown conspicuously, and one month afterwards (June 30; Pl. V, Fig. 40) *Bugula neritina* and *Styela plicata* were in a steady growth.

Test block No. 10 (*immersion on May* 1). On the 12th day (May 12), the surface was found stained by microflora with silt and by a small amount of hydroids and amphipods. Until the 31st day (May 31; Pl. IV, Fig. 31), those microflora and attached animals were growing little but steadily. *Bugula* was conspicuous in growth during the succeeding one month (June 30; Pl. V, Fig. 41), but was destroyed until the end of the following 40 days (August 9; Pl. VI, Fig. 45), leaving healthy *Styela* behind. On the 155th day (October 2; Pl. VII, Fig. 50) continuous growth of *Styela* was still observable.

ii. Experiment B.

Test block No. 1 (*immersion on May* 20). The block still clean and in Stage II of the development of community on the 7th day (May 26) was inhabited by several

Table 2.
Increase and decrease of number in the species occurring on the ten test blocks of Experiment A. +: attachment in the regions surrounding the central region. Lower column: theoretical values computed for every five days. Numerals in bold face: maximum of numbers occurring on ten blocks for a unit time interval. Max.: approximate integer of maximum.

Date		MARCH						APRIL						MAY		
		2	7	12	17	22	27	1	6	11	16	21	26	1	6	11
Spirorbis foraminosus	No. 1		**4**	1 **0.8**		4 **2.2**	2–2	2	0	**2**	**2**	+	0	2	1 0.8	
	No. 2			0		1	5	**3**	2–3	0	1	0	0	0–1	0	1–1 1.7
	No. 3			0			**6**	2	0	0	1	2 1.7	2 2.5	1 0.6	1–1	0
	No. 4			0			1	+	2	0	0–1	2 1.7	1 1.3	2 1.5	2 2.5	0
	No. 5						1	2–1	**3**	+	0	1 0.8	1 1.3	0	2–1 2.3	0–1
	No. 6						0	0	0	0	1	3 **2.5**	2–2 **2.5**	3–1 **1.9**	1–1 1.7	2–1
	No. 7								0	0	+	0	1 1.3	2–1 1.3	0	+
	No. 8										0	0	0	0	4 **6.7**	**8**–1
	No. 9												0	1 0.6	0	4
	No. 10														0	0
	Max.		4	1		2	6	3	3	2	2	3	3	2	7	8
Hydroides norvegica	No. 1		0	0		0	0	0	0	0	0	0	0	0	+	0
	No. 2			0		0	0	0	0	0	0	0	0	0	0	0
	No. 3			0			0	0	0	0	0	0	0	0	0	1 **1.3**
	No. 4			0			0	0	0	0	0	0	0	1 0.7	0	0
	No. 5						0	0	0	0	0	0	0	3 **1.9**	0	+
	No. 6						0	0	0	0	0	0	0	2 1.3	0	1
	No. 7								0	0	0	0	0	1	0	0
	No. 8										0	0	0	0	0	0
	No. 9												0	0	0	0
	No. 10														0	0
	Max.		0	0		0	0	0	0	0	0	0	0	2	1	1

Table 2 continued

Balanus trigonus	No. 1		0	**1**		0	0	0-1	**3**	8	**6**	3 **2.5**	1	57	59 49.0	23-3 **38.3**
	No. 2			0		0	0	0	1	**11**	2-1	2 1.7	3	69 **57.5**	29	18 30.0
	No. 3			0			0	0	0	4	2	0	2	42 26.2	30	6 7.5
	No. 4			0			0	+	0	+	+	0	2 3.0	30 21.4	36-1 45.0	18-1 15.8
	No. 5						0	0	0	1	1	0	2 3.0	27 16.8	46 **76.5**	20-3 16.7
	No. 6						0	0	0	0	1	+	3 **3.7**	12 7.5	35 58.5	16-1
	No. 7								0	1	2	1 0.8	+	6 3.8	11 18.3	21
	No. 8										0	0	0	12 7.5	20-1 33.3	10-1
	No. 9												0	6 3.8	17 28.3	3
	No. 10														0	0
	Max.		0	1		0	0	1	3	11	6	3	4	58	77	38
Balanus tintinnabulum rosa	No. 1		0	0		0	0	0	0	0	0	0	0	**3**	0	4 **6.7**
	No. 2			0		0	0	0	0	0	0	0	+	1 0.8	1	1 1.7
	No. 3			0			0	0	0	0	0	0	0	0	0	0
	No. 4			0			0	0	0	0	0	0	0	1 0.7	1 1.3	0
	No. 5						0	0	0	0	0	0	0	1 0.6	2 **3.3**	+
	No. 6						0	0	0	0	0	0	0	0	0	1
	No. 7								0	0	0	0	0	1 0.6	1 1.7	2
	No. 8										0	0	0	0	0	+
	No. 9												0	0	1 1.7	1
	No. 10														0	0
	Max.		0	0		0	0	0	0	0	0	0	1	3	3	7

Table 2 continued

Bugula neritina	No. 1	0	0		0	0	0	1	0–1	0	1	0	0	0	0
	No. 2		0		0	0	+	+	0	0	0	+	0	+	1 1.7
	No. 3		0			0	0	1	0	0	1 0.8	0–1	1 0.6	0	0
	No. 4		0			0	0	0	0	1	0–1	0	1 0.7	1 1.3	1 0.8
	No. 5					0	0	0	0	0	0	+	0	0	0
	No. 6					0	0	0	0	0	0	0	1 0.6	0	+
	No. 7							0	0	0	0	0	0	0	+
	No. 8									0	0	0	2 1.3	0	0
	No. 9											0	0	0	0
	No. 10													0	0
	Max.	0	0		0	0	1	1	0	1	1	1	1	1	2

Date		APRIL			MAY		
		16	21	26	1	6	11
Bugula californica	No. 1	0	0	1	0	0	1 1.7
	No. 2	0	1 0.8	0–1	0	0	0
	No. 3	0	0	0	1 0.6	0	0
	No. 4	0	0	0	0	0	0
	No. 5	0	0	0	0	1 1.7	0
	No. 6	0	0	0	0	0	0
	No. 7	0	0	0	0	0	0
	No. 8	0	0	0	0	0	0
	No. 9			0	0	0	0
	No. 10					0	0
	Max.	0	1	1	1	2	2

Date		APRIL			MAY		
		16	21	26	1	6	11
Watersipora cucullata	No. 1	0	0	1	0	0	0
	No. 2	0	1 0.8	0	0	0	0
	No. 3	0	0	0	0	+	0
	No. 4	0	0	0	0	0	1 0.8
	No. 5	0	0	0	0	2 3.3	0
	No. 6	0	0	0	0	0	0
	No. 7	0	0	0	0	0	0
	No. 8	0	0	0	0	0	0
	No. 9			0	0	0	0
	No. 10					0	0
	Max.	0	1	1	0	3	1

Table 2 continued

Lichenopora radiata	No. 1	0	0	0	0	0	0
	No. 2	0	0	0	0	0	0
	No. 3	0	0	0	+	0	0
	No. 4	0	0	0	0	0	0
	No. 5	0	0	0	0	0	0
	No. 6	0	0	0	0	1 **1.7**	0
	No. 7	0	0	0	0	0	0
	No. 8	0	0	0	0	0	0
	No. 9			0	0	0	0
	No. 10					0	0
	Max.	0	0	0	1	2	0

Styela plicata	No. 1	0	0	0	0	7	7-1
	No. 2	0	0	0	0	7	18 **30.0**
	No. 3	0	0	0	9 **5.6**	**14**	5-1 6.3
	No. 4	0	0	0	0	1 1.3	10 8.4
	No. 5	0	0	0	0	0	3 2.5
	No. 6	0	0	0	0	0	3
	No. 7	0	0	0	0	0	0
	No. 8	0	0	0	0	0	0
	No. 9			0	0	0	0
	No. 10					0	0
	Max.	0	0	0	6	14	30

Leptoclinum mitsukurii	No. 1	0	0	0	0	1 0.8	0
	No. 2	0	0	0	0	0	0
	No. 3	0	0	0	+	+	0
	No. 4	0	0	0	0	0	0
	No. 5	0	0	0	0	2 **3.3**	1 **0.8**
	No. 6	0	0	0	0	0	0
	No. 7	0	0	0	0	0	+
	No. 8	0	0	0	0	0	+
	No. 9			0	0	1 3.3	0
	No. 10					0	0
	Max.	0	0	0	1	3	1

amphipods, two *Bugula neritina* and six *Leptoclinum mitsukurii* in the central region. Three weeks after initiation (June 9; Pl. VIII, Fig. 53), 92 *Bugula* and 60 *Leptoclinum* were numbered in the central region, though their growth was trivial. On the 31st day (June 19; Pl. VIII, Fig. 54), when the community was in the middle of Stage III, it included a large number of *Bugula* and *Spirorbis foraminosus*, the former attaining to 496 and the latter to 192. The former and *Leptoclinum* had grown into a considerable magnitude. Owing to marked growth of *Bugula*, it was difficult on the 41st day (June 29; Pl. VIII, Fig. 55) to discriminate the new settlers from the pre-existing ones. On the 51st day (July 9; Pl. VIII, Fig. 56), with the extreme growth of *Bugula*, the community attained to the height of Stage IV.

Test block No. 2 (*immersion on May* 30). Elapse of a week (June 5) had already resulted in the attachment of 37 *Leptoclinum mitsukurii* and 3 *Bugula neritina* on the

central region and a small lot of amphipods on the marginal region. This was succeeded by the appearance of a number of *Bugula* and *Leptoclinum* and afterwards the community took a course similar to that of No. 1.

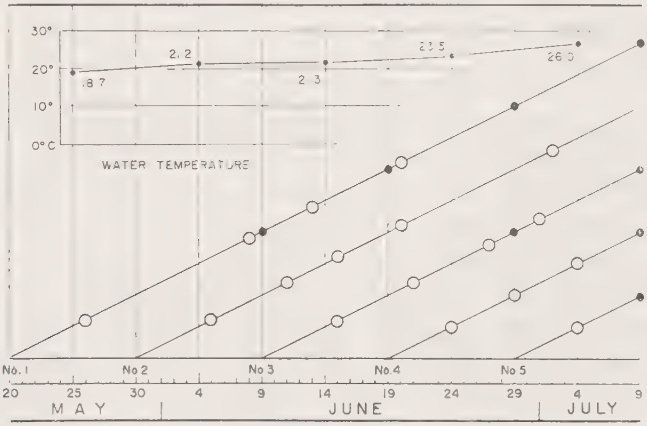

Fig. 2. Experimental plan of series B. As to explanation refer to Fig. 1.

Test block No. 3 (*immersion on June* 9). No matter how it was clean to the naked eye, the surface was stained by 137 *Bugula neritina* and 48 *Leptoclinum mitsukurii* after the first week (June15). On the 13th day (June 21), *Bugula* had increased to 330 in number, while increase of *Leptoclinum* had fallen down. Carrying a small lot of hydroids and amphipods on the marginal region, the community had attained to the middle of Stage II. At the end of the third week (June 29; Pl. VIII, Fig. 57), the community arrived in the middle of Stage III which was marked by conspicuous growth of *Bugula*. Counting the number of animals constituting the community was still feasible and *Bugula* and *Spirorbis* found in the central region were 643 and 224 respectively. Ascertaining the number of *Leptoclinum*, however, was impossible on account of mutual coalescence of closely adjoining colonies. Prosperity of *Bugula* was found on the 31st day (July 9; Pl. VIII, Fig. 58), when the community was in an early phase of Stage IV.

Test block No. 4 (*immersion on June* 19). Although 152 *Bugula neritina*, 65 *Leptoclinum mitsukurii* and 6 *Spirorbis foraminosus* were found in the central region on the 6th day (June 24), neither hydroids nor amphipods were observable. With succeeding steady increase of all of them the community pursued the course similar to that of No. 3 (Pl. VIII, Fig. 59).

Test block No. 5 (*immersion on June* 29). On the 6th day (July 4), *Bugula neritina* was numbered 386, but the attachment of *Leptoclinum mitsukurii* was not so frequent as in the preceding test blocks, only 5 colonies being found. *Spirorbis foraminosus*, *Balanus trigonus* and *Hydroides norvegica* were found one in every case. *Bugula neritina* representing a dominant constituent showed a marked growth until the 11th day (July 9; Pl. VIII, Fig. 60), when the community was near to the middle phase of

Stage III.

3. Differences of communities in their outlook with chronological differences in their initiation

i. Experiment A.

From the observation made above it comes out that the consecutive changes in the "meso-fouling" consist in the following sequence of events. The block surface grows first greenish brown in colour by the attachment and initiation of growth of microflora which are largely composed of sessile diatoms and other minute algae. With their growth the surface becomes "mat-like" in appearance. Under these conditions hydroids make their first appearance on the hemp-palm rope hanging the block, then on the edge of the latter, extending later to the central region. About that time, amphipods begin to build their dwelling tubes. They increase and spread themselves over the surface almost in the same way as in hydroids. Small nudibranchs browsing the hydroids make their appearance among

Tabla 3.

Experiment B. Changes in the number of animals occurring in the central region (20cm × 20cm) of five test blocks. + : occurrence in the rest region. * : total when *Leptoclinum* is excluded. Days: days elapsed after the commencement of experiment.

No. 1

Date	MAY			JUNE					JULY
	20	26	30	4	8	13	20		
Days	0	6	10	15	19	24	31		
Spirorbis foraminosus		0			33	111	192		
Hydroides norvegica		0			+	+	1		
Balanus trigonus		0			1	1	1		
Bugula neritina		2			92	244	496		
Leptoclinum mitsukurii		6			60	—	—		
Total		8			186	356*	690*		

No. 2

Date	MAY			JUNE					JULY
			30	5	11	15	20		2
Days			0	6	12	16	21		33
Spirorbis foraminosus				0	9	14	37		113
Hydroides norvegica				0	0	0	0		0
Balanus trigonus				0	0	0	0		5
Bugula neritina				3	38	106	217		722
Leptoclinum mitsukurii				37	64	93	—		—
Total				40	111	213	254*		840*

Table 3 continued

No. 3

Date	JUNE								JULY
					9	15	21	27	1
Days					0	6	12	18	22
Spirorbis foraminosus						1	18	71	224
Hydroides norvegica						0	2	2	2
Balanus trigonus						0	0	0	1
Bugula neritina						137	330	470	643
Leptoclinum mitsukurii						48	34	—	—
Total						186	384	543*	870*

No. 4

Date	JUNE								JULY
						19	24	29	4
Days						0	5	10	15
Spirorbis foraminosus							6	119	471
Hydroides norvegica							0	0	1
Balanus trigonus							0	0	3
Bugula neritina							152	472	755
Leptoclinum mitsukurii							65	111	—
Total							223	702	1,230*

No. 5

Date	JUNE								JULY
								29	4
Days								0	5
Spirorbis foraminosus									1
Hydroides norvegica									1
Balanus trigonus									1
Bugula neritina									386
Leptoclinum mitsukurii									5
Total									394

the fresh colonies of the latter and lay their spawn vigorously. These animals soon come to an end of their propagation and become to be covered by silt a little by little. After that, the "meso-fouling" begins to show decline, which comes first to hydroids, then gradually to microflora. As a result, "mat-like" growths become extinct leaving a number of amphipod tubes behind. Nudibranchs and their spawns are also extinguished.

Extinction of the "meso-fouling" is an event occurring during the period of the 92nd (May 2)—101st (May 11) days in Test block No. 1, the 83rd (May 3)—91st (May 11) days in No. 2, the 79th (May 9)—83rd (May 13) days in No. 3, the 67th (May 7)—73rd (May 13) days in No. 4, the 54th (May 4)—61st (May 11) days in No. 5, about the 51st day (May 11) in No. 6, the 41st (May 11)—61st (May 31) days in No. 7. The later a community is initiated, the shorter it takes the time to attain this stage.

Macro-fouling in Experiment A consists chiefly of *Spirorbis foraminosus*, *Balanus trigonus* and *Styela plicata*. Of these, the first remains small in size even in the adult, and the last does not grow to a large size by May 11. Development of the community, therefore, owes chiefly to the growth of *Balanus trigonus* until this month. Since *Balanus* is an animal of slow growth, it is overcome afterwards by *Bugula* and *Styela* both of which make their appearance later than *Balanus* and undergo rapid growth.

The time required for the attainment of Stage III (the growth period) in which growth of dominant species becomes distinct (KAWAHARA, 1962), is as follows for each of the blocks. It takes ca. 84 days in Test block No. 1 (April 25; Pl. I, Fig. 1), ca. 74 days in No. 2 (April 25; Pl. I, Fig. 2), ca. 73 days in No. 3 (May 4; Pl. II, Fig. 9), ca. 62 days in No. 4 (May 3; Pl. II, Fig. 10), ca. 53 days in No. 5 (May 4; Pl. II, Fig. 11), ca. 43 days in No. 6 (May 4; Pl. II, Fig. 12), ca. 33 days in No. 7 (May 4; Pl. II, Fig. 13), ca. 30 days in No. 8 (May 11; Pl. III, Fig. 21), and ca. 21 days in No. 9 (May 12). In other words, approximate attainment of the stage is the event on April 25 in Test blocks Nos. 1 and 2, on May 4 in Nos. 3, 4, 5, 6 and 7, and on May 12 in Nos. 8 and 9. Although the time required for attaining to this stage greatly varies according to the test blocks, its date shifts very little. This may be a consequence of the fact that the attachment of *Balanus trigonus* takes place late in the season during which the experiment carried on.

As attached animals continue to grow counting their number becomes sooner or later difficult, or meaningless (Pl. IV, Figs. 22–31). Most of the communities in Experiment A presents the block form in Stage IV (the flourishing period) with an exception of No. 5, which exhibits an encrusting form comprising well-grown *Leptoclinum mitsukurii*. *Bugula neritina* abundantly appearing later and making vigorous growth constructs with its waving apical part an erecting form community late in July (Pl. V, Figs. 32–41). Flourishing colonies of *Bugula neritina* become withered before long and almost simultaneously on all the blocks, the community restoring block form (Pl. VI, Figs. 42–45). A similar extinction of dominant species, especially of *Styela plicata*, occurs afterwards (Pl. VII, Figs. 47–50). In this case, the decline is not a simultaneous event in all communities unlike in *Bugula neritina* (KAWAHARA, 1960).

Under these circumstances as detailed above, all the communities in Experiment A result in the community type of the same kind. On the contrary, the communities developing on Test blocks Nos. 11–16, which were put to the test succeedingly, and the results of which will be related in future, exhibited different

community type, since the season of *Styela* attachment had been over (Pl. VI, Fig. 46; Pl. VII, Figs. 51 and 52).

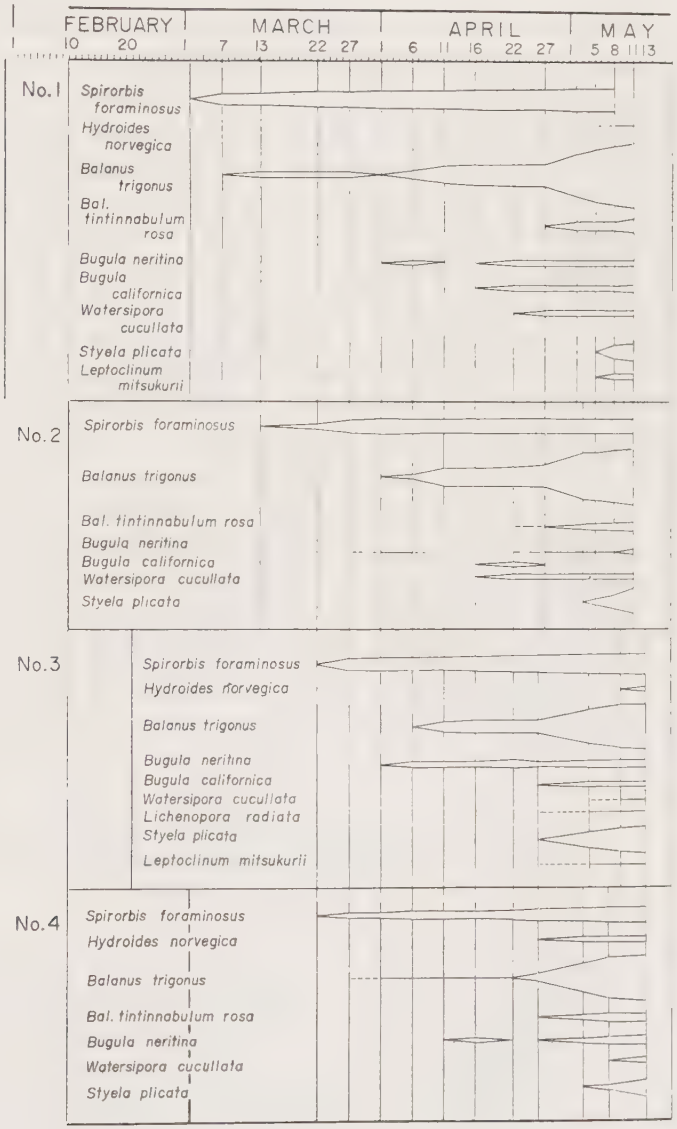

Fig. 3. Chronological changes in the number of animals constituting the communities in Experiment A. Ordinates are proportional to the diameters of circles, by whose areas the numbers are represented.

ii. Experiment B.

The season in which Experiment B was made was best fitted for the attachment of fouling animals. The macro-fouling took place as soon as the test blocks

were thrown in the sea. Although the "meso-fouling" is indistinct in this case, it appears to take place simultaneously with the macro-fouling. Major foulers in this experiment are *Spirorbis foraminosus*, *Bugula neritina* and *Leptoclinum mitsukurii*. Of these, the last two determine the nature of community, dominancy of *Bugula* representing the erecting form and that of *Leptoclinum* the encrusting form.

Development of communities dominated by *Bugula neritina* is as follows. In Test block No. 1, the community entered Stage III (the growth period) approximately on the 21st day (June 9; Pl. VIII, Fig. 53). Counting the number of constituents is feasible until the 31st day (June 19; Pl. VIII, Fig. 54). By the vigorous growth of the apical part *Bugula* begins to hung in the water, presenting a jungle-like appearance of Stage IV (the flourishing period) after about twenty days (July 9; Pl. VIII, Fig. 56). As time passes, attachment of *Bugula* is more and more invigorated and its growth is accelerated, so that the length of time necessary for Test block No. 1 to reach the middle phase of Stage III (on the 31st day, June 19; Pl. VIII, Fig. 54) is reduced by ten days in No. 3 (June 29; Pl. VIII, Fig. 57) and by another ten days in No. 5 (July 9; Pl. VIII, Fig. 60).

When two neighbouring colonies of *Leptoclinum mitsukurii* grow so large as to come into contact with each other, they are coalesced together into a single colony. This is the reason why mere counting of number becomes meaningless. This takes place approximately on the 25th day in Test block No. 1, on the 21st day in No. 2, and on the 16th day in No. 3 and No. 4. Shortening in the time required is chiefly due to that the attachment is accelerated with the time passes. By the repetition of coalescence, the colonies grow larger and larger, and this will prove a hindrance to the attachment of other sessile animals. Initial state of substratum will be in this way disturbed.

4. Change in the number of individuals and species constituting a community

i. Experiment A.

Species appearing on the blocks are numbered 11. Chronological change in the number of individuals or colonies in each community are shown in Table 1. Species appearing on Test block No. 1 are 9 in number, they are 7 on No. 2, 9 on No. 3, 7 on No. 4, 9 on No. 5, 7 on No. 6, 6 on No. 7, 5 on No. 8, and 4 on No. 9. Generally speaking, the number of species is smaller in younger community than in older one.

In comparing various communities with respect to the number of individuals it seems convenient to represent this by the diameter of a circle, area of which is correlative to the real number. This is a modification of Lohmann's "Kugelkurvenmethode" (LOHMANN, 1908), which is applied here to the two dimensions. A similar way of representation has been adopted by some authors, for example by KNIGHT-JONES (1952), in whose work the number of *Elminius modestus* has been represented

by the area of a square. In making the graph of the present study, however, the animal number is expressed by its square root, that is, by the magnitude of one side of that square.

In Figs. 3 and 4, which illustrates the chronological changes in the number of individuals and species occurring in nine test blocks, the square root is taken on the ordinate. It may be seen from these diagrams that all the communities are similar in their component species and in the successive changes of the individual number. Increase and decrease of number during every time interval is shown in Table 2

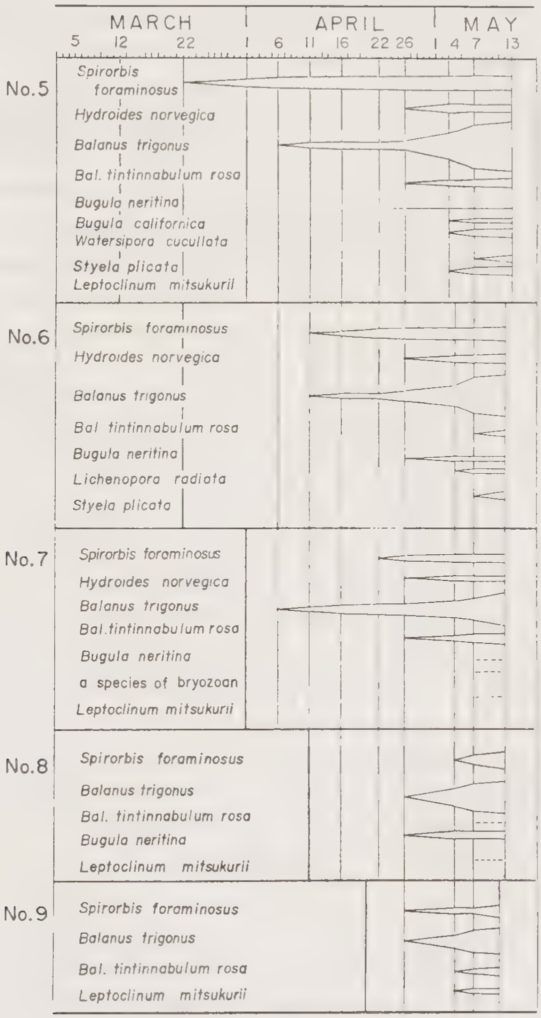

Fig. 4. Same.

for each species separately. Numbers computed from these data for every five days are also added to the table. The maximum among the numbers found in ten

blocks is indicated in bold face for each time interval. The numerical values are presumed to represent the transition of attaching activity if the experiment were made sufficiently in a large scale. The sequence of changes will be perceivable from the graph of Fig. 5.

As may be seen from the figure, attaching activity of *Spirorbis foraminosus* is disclosed early in March, though rare in its appearance. The species continues

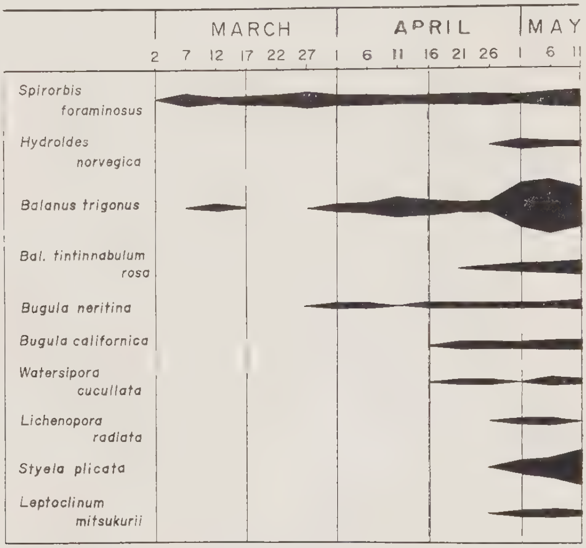

Fig. 5. Theoretical transition in the attaching activity in the field deduced from Experiment A. Square roots of the maxima shown in Table 2 are taken on ordinates.

afterwards its attachment steadily, without showing any appreciable increase of the activity with the advance of season. *Balanus trigonus* enters its attaching season subsequent to *Spirorbis*. Its attachment which is exceptional in March is gradually increasing from April onwards, and most vigorous in May. Activity of *Bugula neritina* begins in April but is not augmented very much until June. That of *Bugula californica* and *Watersipora cucullata* is commenced late in April and that of *Hydroides norvegica*, *Balanus tintinnabulum rosa*, *Lichenopora radiata* and *Leptoclinum mitsukurii* early in May. In these species the occurring number is very small. Attachment of *Styela plicata* begins to be activated from May on and in a large number which increases steadily.

Attachment of *Spirorbis foraminosus* and *Balanus trigonus* on the test blocks falls some length of time behind the first immersion of them in water in spite of that they are in the season active in attachment (Figs. 3, 4 and 5). This delay becomes step by step shortened as the community is established later. Similar tendency is observable also in other species in some measure.

Here let us consider two kinds of total of individuals having attached to each of the ten test blocks. One is the total individuals comprised in a community at

the end of a definite observation interval (α) and the other is the total of the numerals which represent the maximum of the numbers having attached to the respective ten blocks during each observation interval until that time (β). It may be presumed that β is near to represent the extent of attaching activity in natural state (cf. p. 410). In *Spirorbis* and *Balanus*, α is far smaller than β at any time period. Largeness of the difference in the two values may originate in the feebleness of those species in their activity, since if these would be vigorous, the difference would be much smaller.

Distribution of numerals represented by bold face tells that the most vigorous attachment of *Spirorbis foraminosus* occurs in the community of a comparatively early stage. On April 21, for example, this occurs on Test block No. 6 of 8 communities, on May 1 on No. 6 of 9 communities, on May 6 on No. 8 of 10 communities and on May 11 on No. 8 of 10 communities. *Balanus trigonus*, on the contrary, is more frequent in the community of comparatively advanced stage. It is most frequent in Test block No. 1 of 8 communities on April 21, in No. 2 of 9 communities on May 1, in No. 5 of 10 communities on May 6, and in No. 1 of 10 communities on May 11. Similar phenomenon can be seen in other species to a greater or less extent, however small the attaching number is.

ii. Experiment B.

Species attaching to the block during the course of this experiment are five in all. Of these, the major species are *Spirorbis foraminosus*, *Bugula neritina* and *Leptoclinum mitsukurii*. Successive changes in the number of species and individuals appearing on the test blocks are given in Table 3. These are represented diagrammatically in Figs. 6 and 7. As may be seen, five communities are quite resembling to one another in their component species as well as in the numerical changes of these.

Increase in the number of individuals for each species is listed in Table 4 in which the numerals correspond to the computation value for every five days as in Experiment A. Successive changes in the attaching activity of animals are illustrated in Fig. 8 by the same procedure as in Experiment A. *Leptoclinum mitsukurii* attaching to the block in a large number late in May sustains its activity until early July. Making its first appearance in May, *Bugula neritina* increases much in number in June, being especially abundant from the middle decade of that month on. *Spirorbis foraminosus* appearing in a large number in June is accelerated in its attaching as time passes.

These species belong to the ones appearing in the earliest stage of community, while *Hydroides norvegica* and *Balanus trigonus* are somewhat delayed in their settlement (Figs. 6 and 7). This delay may be ascribable to their feeble activity at that time. In *Bugula* and *Leptoclinum* difference between α and β (refer to above) is not so large as in *Spirorbis* and *Balanus* of Experiment A. This may be due to the vigorous activity of those speices in contrast to the feeble one of these.

Judging from the numerical value shown in bold face in Table 4, *Spirorbis*

Table 4.
Changes in the number of attachment in Experiment B, illustrated as in Table 2.

	Date	MAY		JUNE						JULY
		25	30	4	9	14	19	24	29	4
Spirorbis foraminosus	No. 1	0			33 **12.7**	**78**	81 **57.9**			
	No. 2			0	9 7.5	5 6.3	23		76 31.6	
	No. 3					1 0.8	17 14.2	53 **44.2**	153 **181**	
	No. 4							6	113	**352**
	No. 5									1
	Max.	0		0	13	78	58	44	181	352
Hydroides norvegica	No. 1	0			+	+	1 0.7			
	No. 2			0	0	0	0		0	
	No. 3					0	2 **1.4**	0	0	
	No. 4							0	0	1
	No. 5									**1**
	Max.	0		0	1	1	2	0	0	1
Balanus trigonus	No. 1	0			1 **0.4**	0	0			
	No. 2			0	0	0	0		5 **2.1**	
	No. 3					0	0	0	1 1.3	
	No. 4							0	0	**3**
	No. 5									1
	Max.	0		0	1	0	0	0	2	3
Bugula neritina	No. 1	2 **1.7**			90 **34.6**	**152**	252 180			
	No. 2			3 **2.5**	35 29.2	68 85	111		506 210	
	No. 3					137 114.2	293 **244**	140 117	173 216	
	No. 4							**152**	**320**	283
	No. 5									**386**
	Max.	2		3	35	152	244	152	320	386

Table 4 continued

Leptoclinum mitsukurii	No. 1	6 **5.0**			54 20.8					
	No. 2			37 **30.8**	27 **22.4**	29 36.2				
	No. 3					48 **40.0**	14 **11.7**			
	No. 4							**65**	**46**	
	No. 5									**5**
	Max.	5		31	22	40	12	65	46	5

foraminosus prefers an advanced community in joining this on account of its feebleness in attaching activity. Nevertheless, as the activity of the species grows vigorous, so it becomes to make its appearance in an earlier developmental stage of community.

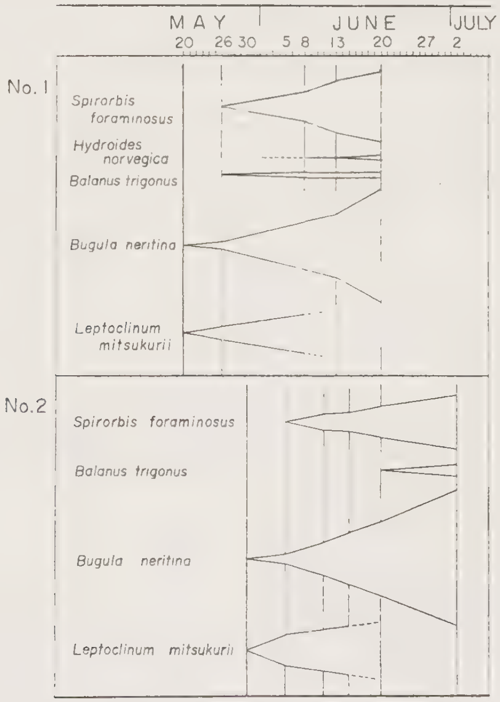

Fig. 6. Chronological changes in the number of animals constituting the communities in Experiment B. Ordinates are proportional to the diameters of circles, by whose areas the numbers are represented.

munity. Such is also the case with *Bugula neritina*. *Leptoclinum mitsukurii* alone seems to be fond of settling down only in an early stage of community.

5. Consideration

a. Patterns of fouling and process of "meso-fouling".

Many of the authors have taken notice of the existence of micro-fouling (or primary films) originating in bacteria and other micro-organisms (ZoBELL & ALLEN, 1935; MILLER, RAPEAN & WHEDON, 1948) in addition to macro-fouling caused by larger organisms. The tiny fouling algae, for instance, *Ectocarpus* spp. and such sessile diatoms as *Navicula* spp. come between the two kinds of foulers in their volume as well as in the rapidity of their development. Though some authors include them in the film makers, as FULLER (1946) does, others pay attention to certain other characteristics of those algae. According to the report from Woods Hole Oceanographic Institution (1952) it is said that as soon as the substratum is put into the sea it becomes covered by bacteria which rapidly grow, whereas during the first two or three days it is destitute of algae or diatoms which are propagated rapidly afterwards. PYEFINCH (1948) suggests that *Ectocarpus* and other sea weeds grow into thin, mat-like growths more persistent than bacterial and diatomaceous slimes. The present author made, in his previous paper (KAWAHARA, 1962), a proposition to call this type of fouling "meso-fouling" to distinguish it from macro- and micro-foulings.

Colonies of hydroids so delicate as those of *Obelia* and *Clytia* can be referred to "meso-fouling" as regards their developmental changes. Small-sized nudibranchs swarm about the hydroids to browse on these and lay their spawn here and there. This has been observed by ORTON (1930), PAUL (1942) and others. Dwelling tubes of amphipods join the community at the same time and can be found at times in a large number as recorded by COE & ALLEN (1937). Associated with the fouling by minute algae and sessile diatoms, they constitute the "meso-fouling" in a wide sense of the word.

General sequence of changes in the "meso-fouling" has been mentioned in chapter 3. Extinction of the "meso-fouling" is somewhat abrupt one in most of the communities in Experiment A, and this appears to owe to the peculiarity of the season.

b. Role of dominant species and fate of community.

Developmental stage of a community may be told approximately by the growth extent of dominant species, and the characteristics of the former may be under the control of the life form of the latter. The life forms of fouling animals can be divided into three: block, erecting and encrusting forms (KAWAHARA & IIZIMA, 1960). In the present experiment, the first is represented principally by *Balanus trigonus*, *Styela plicata* and *Spirorbis foraminosus*, the second by *Bugula neritina* and *Obelia geniculata* and the third by *Leptoclinum mitsukurii* and *Watersipora cucullata*. *Hydroides norvegica* which belongs to the block form in this case often grows into an erecting form as this has been observed by EDMONDSON (1944) in Hawaii. The three forms

differ one from another not only in their characters, but also in their development and span of life. Generally speaking, the encrusting form is the shortest in their span of life, the erecting one coming to the next and the block one is the longest. On the contrary, the rapidity of their development is completely reversed in order. Block forms is at times overcome by erecting forms and often even by encrusting forms. For instance it may be quoted from the report from Woods Hole Oceanographic Institution (1952) that *Balanus improvisus* community is overcome by compound ascidians appearing later.

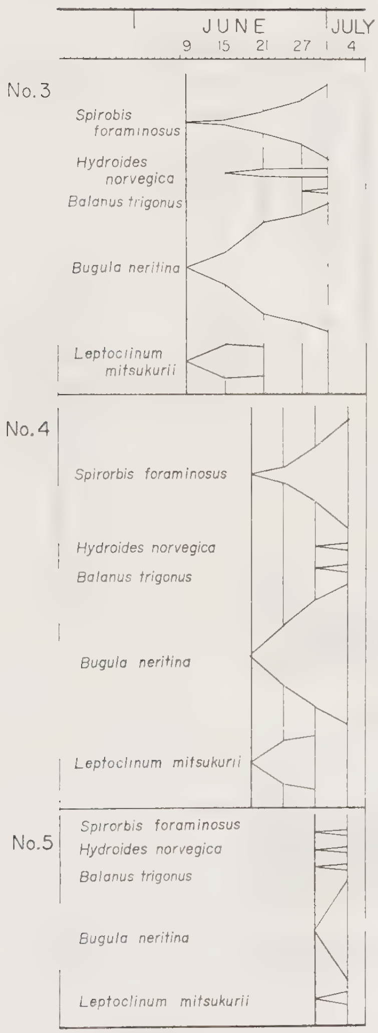

Fig. 7. Same.

When these dominants become extinct, the original surface is again exposed here and there so as to provide new immigrants with better substratum. Similar suquence of events is commenced here again on this exposed region (KAWAHARA, 1960). Through the repetition of such cycles differences in the initial phase of communities becomes more and more obliterated.

c. Developmental stages of communities favourable for the attachment of particular species.

Selection of substratum by sessile animals is determined by a number of factors. Physical and chemical conditions of substratum were studied by POMERAT & WEISS (1946), BARNS & POWELL (1950) and others in some detail. In case of epiphytic or epizoic organisms, the problem is somewhat of different kind. DE SILVA (1962) and RYLAND (1962) say of the larvae of tube worms and bryozoans as prefering certain definite species of algae as a substratum for their attachment. In these cases, the attachment is under the influence of the growths preceding them.

Environment constitutes another important factor. While the development of a community is arrested, the environmental conditions on the substratum are apt to change and to become adverse to the organisms. As the former goes on, the latter becomes favourable owing to the protection by the growth of pioneer species. Species capable of standing any environmental conditions can attach themselves to the block surface even in an earlier stage of community, whareas those which are

sensitive to the change of conditions are forced to join the community only when it is favourable for them. Data indicated in bold face in Tables 2 and 4 suggest that the sessile animals make to a certain extent the selection of developmental stages in which they attach themselves to the substratum, even if these data are not very many. Considering the matter from this point of view, it may come out that *Leptoclinum mitsukurii*, *Spirorbis foraminosus* and *Bugula neritina* join the community at an earlier stage and *Balanus trigonus* and *Styela plicata* do somewhat later.

While a species is in the height of its attaching activity, it is capable of settling down even in a stage earlier than usual. *Bugula neritina* in Table 4 may be regarded as to represent an example of this tendency. On account of this, the initial community is apt to be simplified in constitution.

d. Attaching activity of organisms in the field.

How to seize the exact knowledge of attaching activity of organisms in the field belongs to one of the fundamental problems. A lot of studies have been made with respect to the effect of various physical and chemical conditions on the attachment of organisms. POMERAT & WEISS (1946) made a research on the texture of

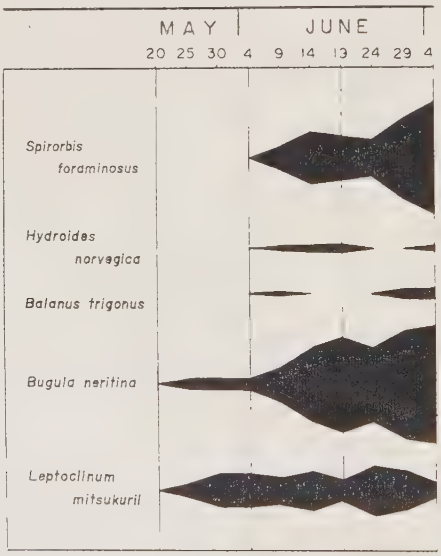

Fig. 8. Theoretical transition in the attaching activity in the field deduced from the Experiment B. Square roots of the maxima shown in Table 4 are taken on ordinates.

the surface, POMERAT & REINER (1942) on the angle of the surface, WEISS (1947) on illumination, SMITH (1946), DOOCHIN & SMITH (1951) and WOOD (1955) on water current. Attachment of organisms depends greater or less on these varieties of conditions. In this connection, it may be said that a cautionless test block experiment is useless for seizing real state of seasonal changes in the attaching activity of organisms in the field. Nevertheless, a plausible conjecture may be given by

making experiment on a substratum with the condition best for the attachment of organisms.

Since the concrete block is a substratum good for the attachment of organisms and various developmental stages of communities growing on it may provide varieties of species with favourable environment, it may be well to say that a conjecture on what is going on in the field will be to a certain extent deducible from the present experiment.

Summary

1) In the early summer of 1944 (Experiment B) and in the spring of 1946 (Experiment A) at Tomioka, Amakusa, Kyūshū, periodical observations of the fouling communities were made on a series of test blocks thrown in the sea at regular intervals.

2) In experimental series A the development of "meso-fouling" caused by sessile diatoms and other minute algae was conspicuous. It was associated with the appearance of hydroids, nudibranchs and amphipods, and exhibited in all a characteristic alternation of prosperity and decay in all of the test blocks.

3) Communities developing on the test blocks immersed in the sea one by one at regular intervals were divisible into several groups according to the attaching season of dominant species.

4) It is presumed that when the dominant becomes extinct, the original surface is again exposed, and by the repetition of a similar process on the re-exposed surface the difference in the initial phase of communities will be obliterated more and more.

5) *Leptoclinum mitsukurii*, *Spirorbis foraminosus* and *Bugula neritina* make their appearance in an earlier stage, and *Balanus trigonus* and *Styela plicata* somewhat later. When they are in the height of their attaching season, they are capable of appearing even in a stage earlier than usual, so that the initial community is apt to be simplified in its constitution in this case.

6) If a species is feeble in its attaching activity, the number of animals to be found in an unfavourable substratum may be much smaller than usual. On the contrary, if the animal is in the height of its attaching activity, there may be little difference between the favourable and unfavourable substrata with respect to the number of attaching individuals.

7) As to finding the seasonal variation in the attaching activity of sessile animals in the field a deduction may effectively be drawn from examining their attachment on the test blocks which are in a state best for their development.

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Explanation of Plate I

Various stages of the developement of fouling communities on the test blocks (Experiment A). (× 1/3).

Figs. 1-6. Communities of April 22 or 25, showing gradation of "meso-fouling".

Fig. 1. Test block No. 1, 82nd day (April 22)
Fig. 2. Test block No. 2, 75th day (April 25)
Fig. 3. Test block No. 3, 62nd day (April 22)
Fig. 4. Test block No. 4, 52nd day (April 22)
Fig. 5. Test block No. 5, 42nd day (April 22)
Fig. 6. Test block No. 6, 32nd day (April 22)

Fig. 1.

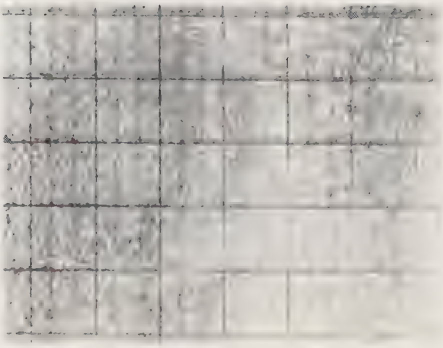


Fig. 2.

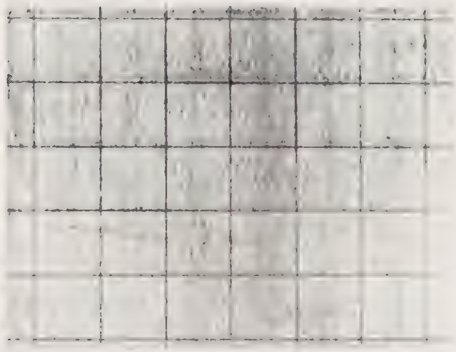


Fig. 3.

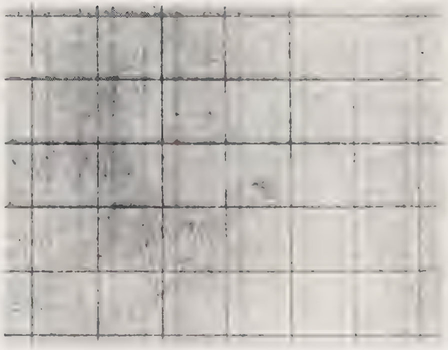
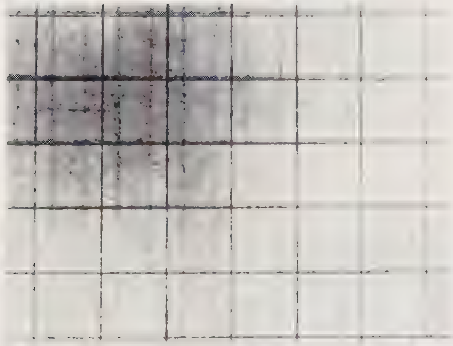


Fig. 4.



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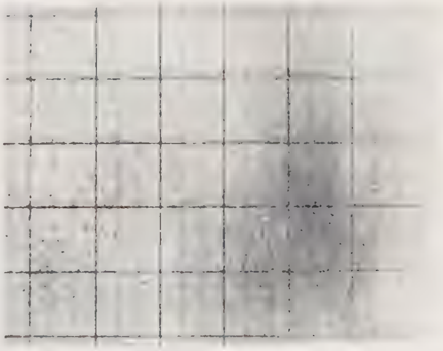


Fig. 6.

Explanation of Plate II

Same.

Figs. 7–13. Communities during the period from May 2 to 4, showing commencement of decline of "meso-fouling" and growth of barnacles.

Fig. 7. Test block No. 1, 92nd day (May 2)
Fig. 8. Test block No. 2, 83rd day (May 3)
Fig. 9. Test block No. 3, 74th day (May 4)
Fig. 10. Test block No. 4, 63rd day (May 3)
Fig. 11. Test block No. 5, 54th day (May 4)
Fig. 12. Test block No. 6, 44th day (May 4)
Fig. 13. Test block No. 7, 34th day (May 4)

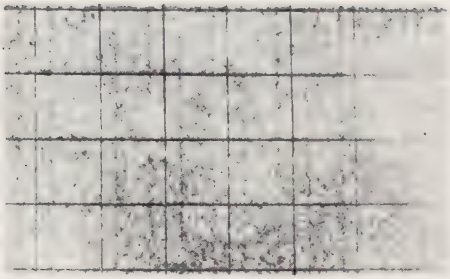


Fig. 7.

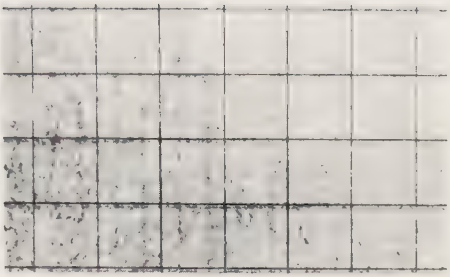


Fig. 8.

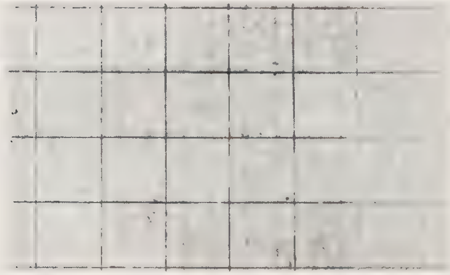


Fig. 9.

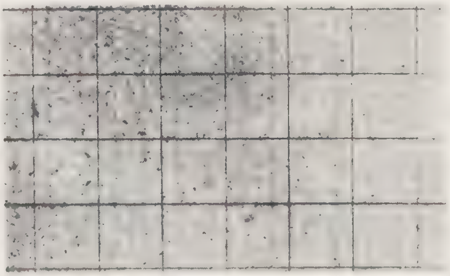


Fig. 10.

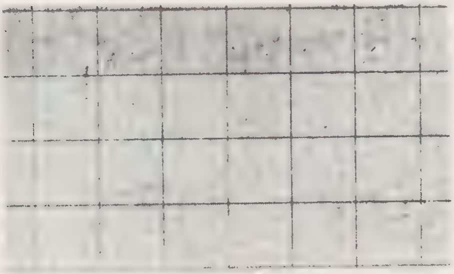


Fig. 11.

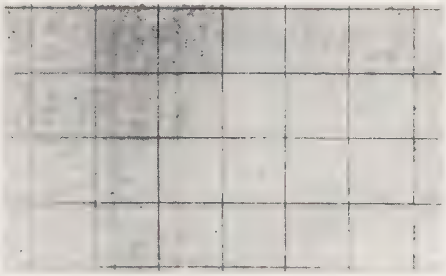


Fig. 12.

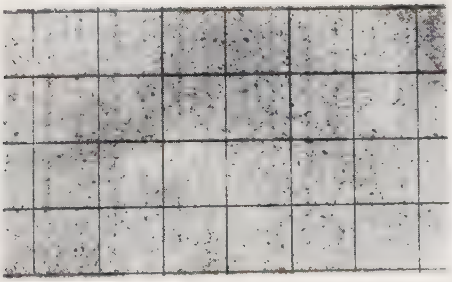


Fig. 13.

Explanation of Plate III

Same.

Figs. 14–21. Communities of May 11, showing "meso-fouling" extinction and survived amphipod tubes.

Fig. 14. Test block No. 1, 101st day (May 11)
Fig. 15. Test block No. 2, 91st day (May 11)
Fig. 16. Test block No. 3, 81st day (May 11)
Fig. 17. Test block No. 4, 71st day (May 11)
Fig. 18. Test block No. 5, 61st day (May 11)
Fig. 19. Test block No. 6, 51st day (May 11)
Fig. 20. Test block No. 7, 41st day (May 11)
Fig. 21. Test block No. 8, 31st day (May 11)

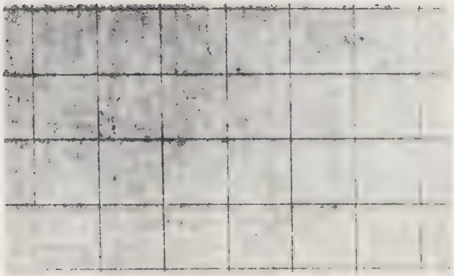


Fig. 14.

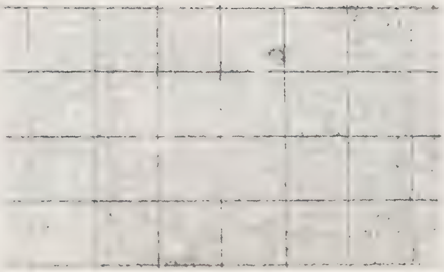


Fig. 15.

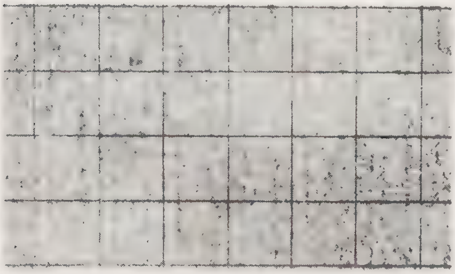


Fig. 16.

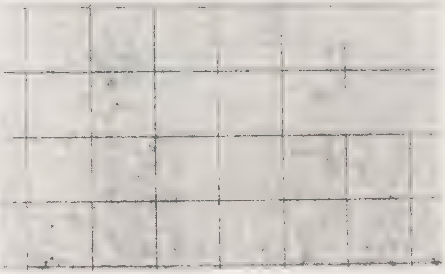


Fig. 17.

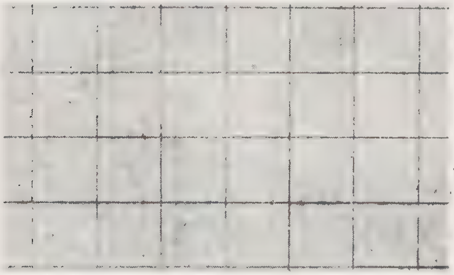


Fig. 18.

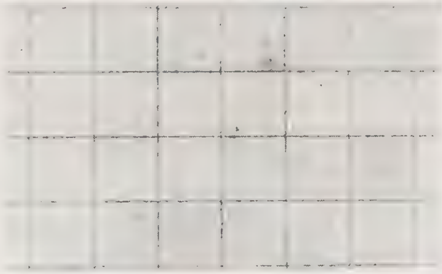


Fig. 19.

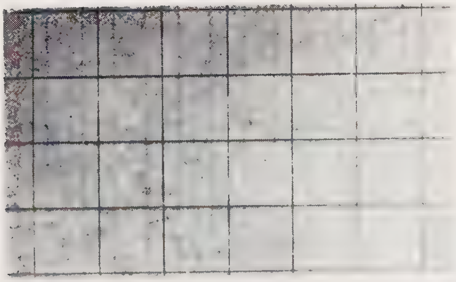


Fig. 20.

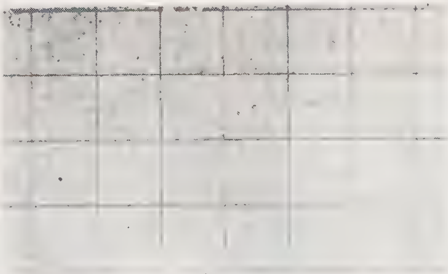


Fig. 21.

Explanation of Plate IV

Same.

Figs. 22-31. Communities of May 31, showing bulky fouling.

Fig. 22. Test block No. 1, 121st day (May 31)
Fig. 23. Test block No. 2, 111th day (May 31)
Fig. 24. Test block No. 3, 101st day (May 31)
Fig. 25. Test block No. 4, 91st day (May 31)
Fig. 26. Test block No. 5, 81st day (May 31)
Fig. 27. Test block No. 6, 71st day (May 31)
Fig. 28. Test block No. 7, 61st day (May 31)
Fig. 29. Test block No. 8, 51st day (May 31)
Fig. 30. Test block No. 9, 41st day (May 31)
Fig. 31. Test block No. 10, 31st day (May 31)

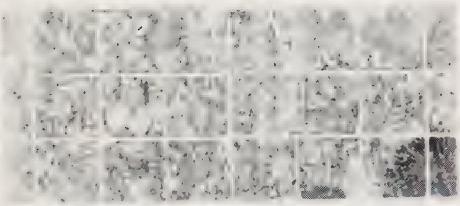
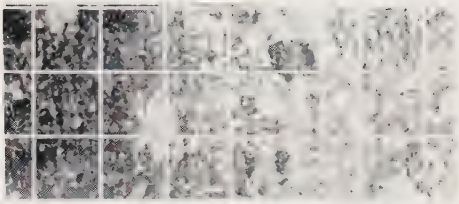


Fig. 22.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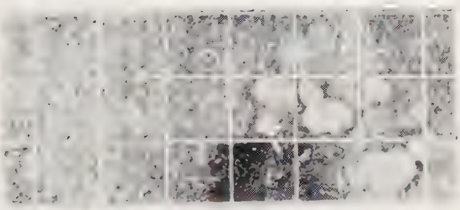
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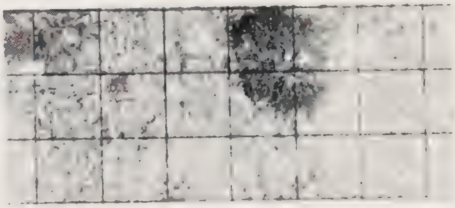
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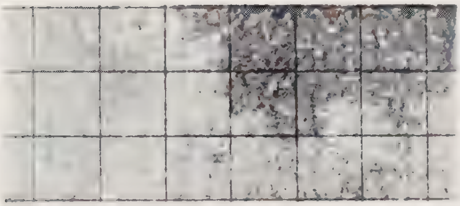


Fig. 26.

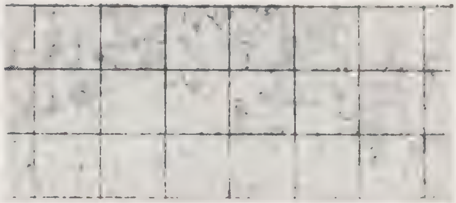


Fig. 27.

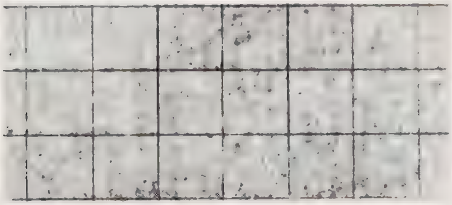


Fig. 28.

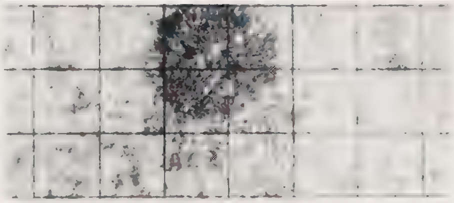


Fig. 29.

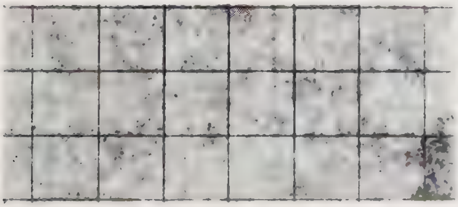


Fig. 30.

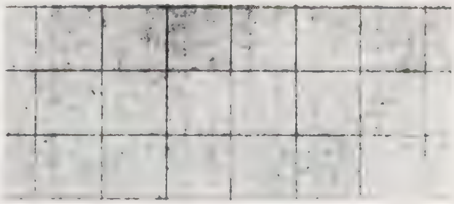


Fig. 31.

Explanation of Plate V

Same.

Figs. 32–41. Communities of June 30, showing jungle-like growth of flourishing *Bugula neritina* and *Styela plicata*.

Fig. 32. Test block No. 1, 151st day (June 30)
Fig. 33. Test block No. 2, 141st day (June 30)
Fig. 34. Test block No. 3, 131st day (June 30)
Fig. 35. Test block No. 4, 121st day (June 30)
Fig. 36. Test block No. 5, 111th day (June 30)
Fig. 37. Test block No. 6, 101st day (June 30)
Fig. 38. Test block No. 7, 91st day (June 30)
Fig. 39. Test block No. 8, 81st day (June 30)
Fig. 40. Test block No. 9, 71st day (June 30)
Fig. 41. Test block No. 10, 61st day (June 30)

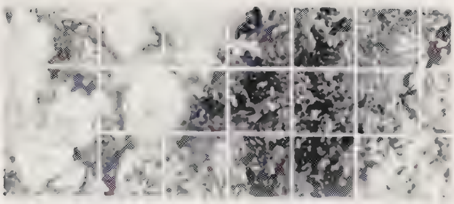


Fig. 32.

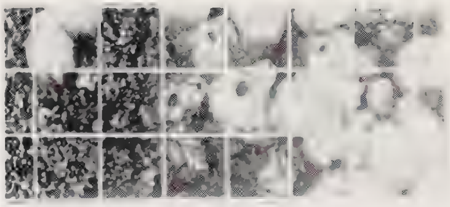


Fig. 33.

Fig. 34.

Fig. 35.

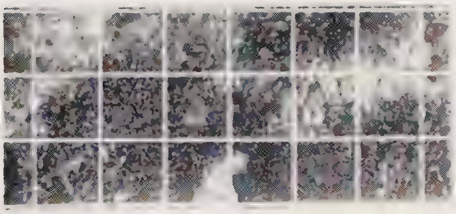


Fig. 36.

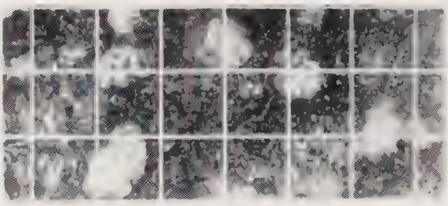


Fig. 37.

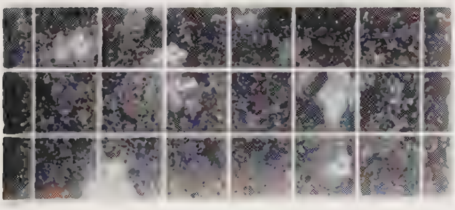


Fig. 38.

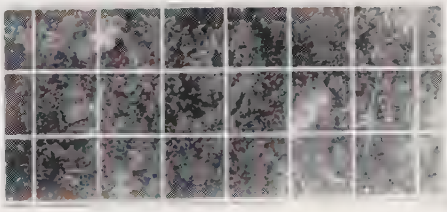


Fig. 39.

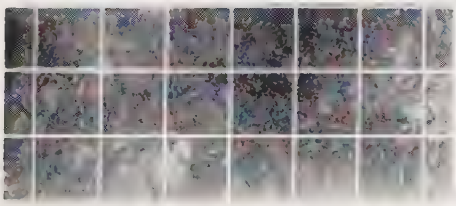


Fig. 40.

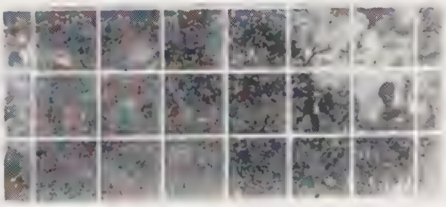


Fig. 41.

Explanation of Plate VI

Same.

Figs. 42–45. Communities of August 9, showing extinction of *Bugula neritina* and flourish of *Styela plicata*.

Fig. 42. Test block No. 1, 191st day (August 9)

Fig. 43. Test block No. 4, 161st day (August 9)

Fig. 44. Test block No. 7, 131st day (August 9)

Fig. 45. Test block No. 10, 101st day (August 9)

Fig. 46. Community deprived of *Styela*. Test block No. 13, 71st day (August 9)

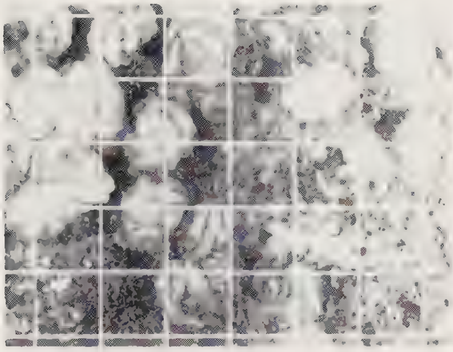


Fig. 42.

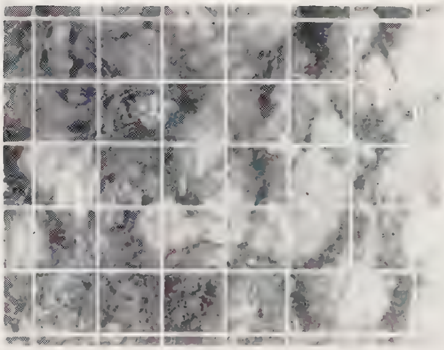


Fig. 43.

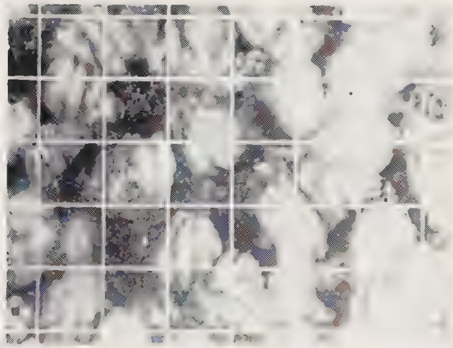
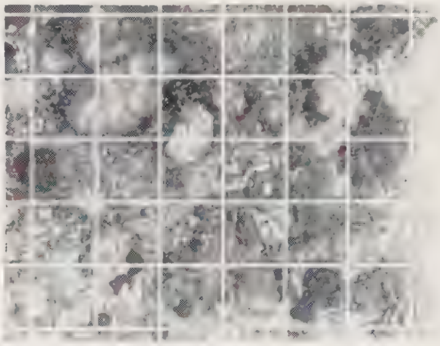


Fig. 44.



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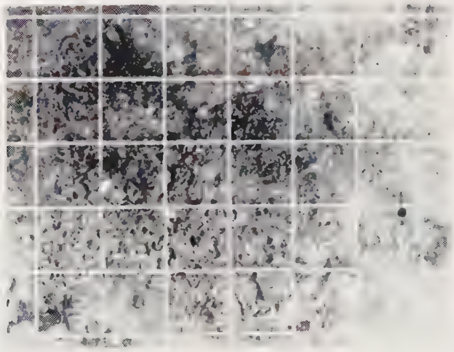


Fig. 46.

Explanation of Plate VII

Same.

Figs. 47–50. Communities of October 2, showing decline of *Styela.*

Fig. 47. Test block No. 1, 245th day (October 2)
Fig. 48. Test block No. 4, 215th day (October 2)
Fig. 49. Test block No. 7, 185th day (October 2)
Fig. 50. Test block No. 10, 155th day (October 2)

Figs. 51–52. Communities lacking in *Styela.*

Fig. 51. Test block No. 13, 125th day (October 2)
Fig. 52. Test block No. 16, 95th day (October 2)

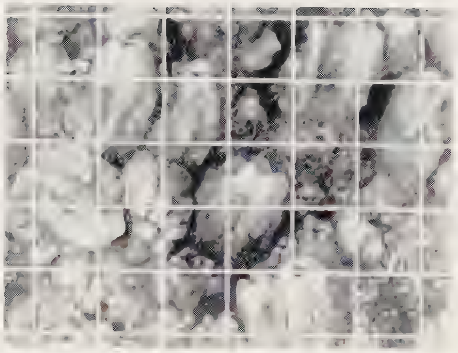


Fig. 47.

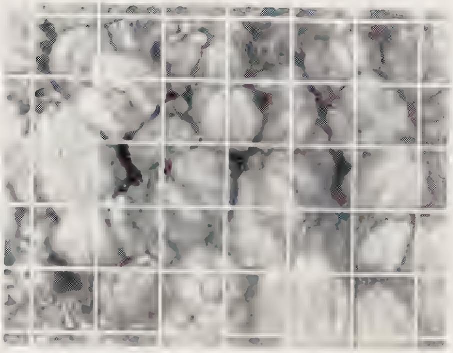


Fig. 48.

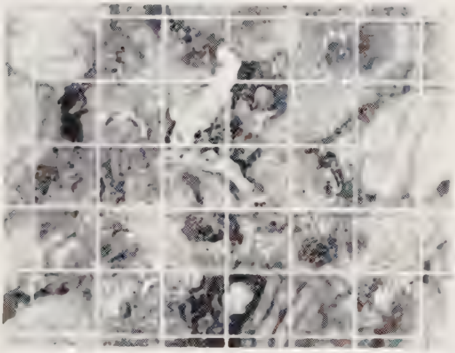


Fig. 49.

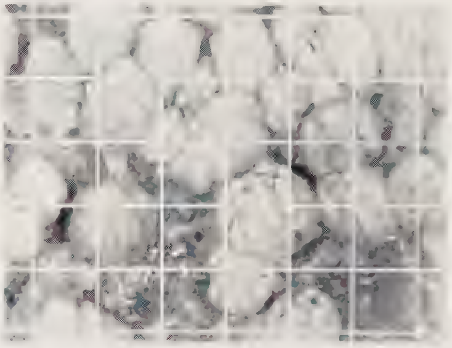


Fig. 50.

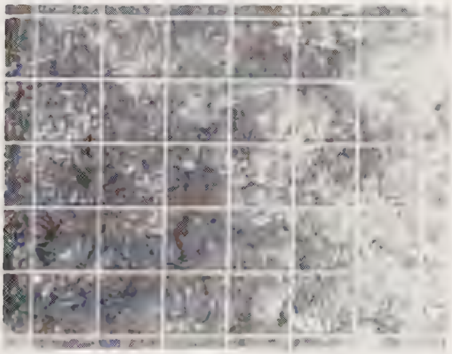


Fig. 51.

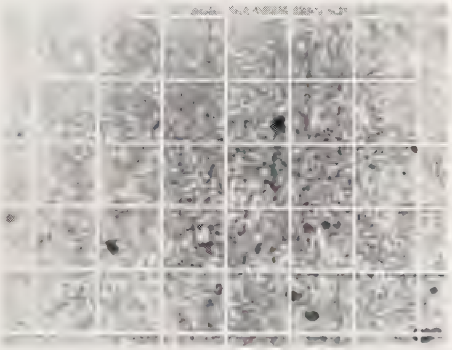


Fig. 52.

Explanation of Plate VIII

Figs. 53–56. Successive changes in the test block fouling communities (in Experiment B), showing marked attachment and growth of *Bugula neritina*.

Fig. 53. Test block No. 1, 21st day (June 9)
Fig. 54. Test block No. 1, 31st day (June 19)
Fig. 55. Test block No. 1, 41st day (June 29)
Fig. 56. Test block No. 1, 51st day (July 9)

Figs. 57–60. Acceleration of attachment and growth of *Bugula neritina*.

Fig. 57. Test block No. 3, 21st day (June 29)
Fig. 58. Test block No. 3, 31st day (July 9)
Fig. 59. Test block No. 4, 21st day (July 9)
Fig. 60. Test block No. 5, 11th day (July 9)

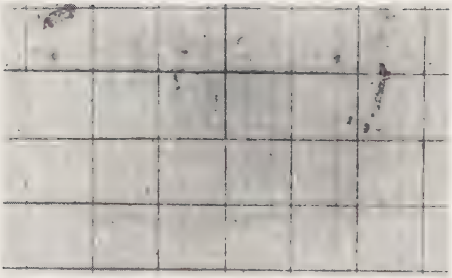


Fig. 53.

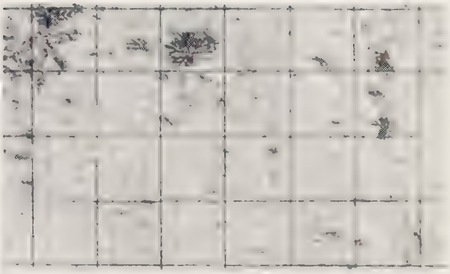


Fig. 54.

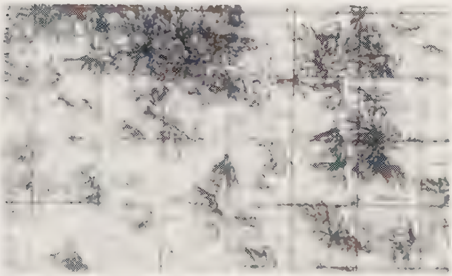


Fig. 55.

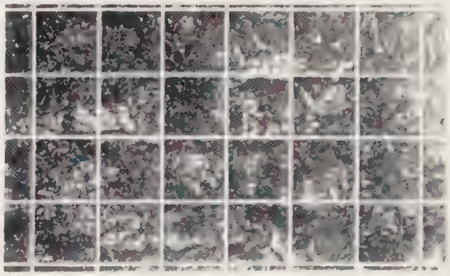
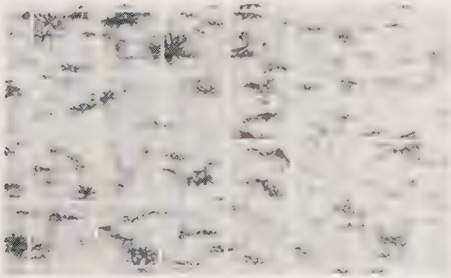


Fig. 56.



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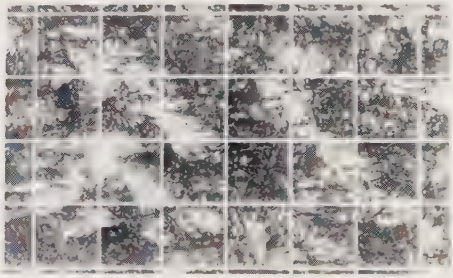

Fig. 58.

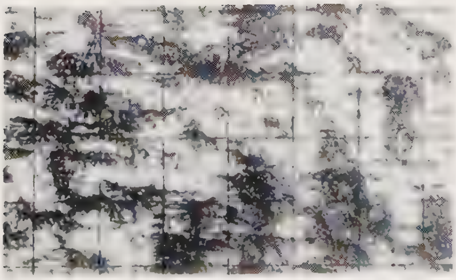

Fig. 59.

Fig. 60.

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On Two New Notodelphyoid Copepods from the Bay of Matoya

Shigeko Ooishi

Two new Notodelphyoid Copepods to be described here were collected in the bay of Matoya, Mie Prefecture. They were referrable to the genus *Paranotodelphys* and *Pachypygus*.

Paranotodelphys villosus n. sp.

Occurrence: Five females were obtained in *Ascidia sydneiensis samea* (Oka) on January 26, 1961. The host examined was 10 in number and 5 of them contained this parasite together with a species of *Ascidicola* in most of the cases.

Female: Body straightened (Fig. 1, A, B, D) without showing ventral flexure, and invested by hard integument scattered by very minute spinules on the surface. Length from the top of prosome to the end of caudal rami 2.9 mm. Body divisible into prosome, 4-segmented metasome and 5-segmented urosome. Prosome produced in front into an elongate, subtriangular rostal plate. Last metasomal segment accomodates the embryos with oblong, comparatively narrow brood pouch which occupies one-third of entire body. Fifth legs vestigial, located near posterior edge of brood pouch. Urosome (Fig. 1, C) relatively slender; proportional lengths of its segments measured on ventral lines as 5: 7: 7: 7: 7. Genital apparatus near the posterior margin of 1st urosomal segment. Caudal ramus elongate, 4/5 as long as urosome and 1/5 as long as body.

Antennule (Fig. 1, E) 9-jointed, reaching posterior two-thirds of prosome. First 2 joints short as compared with their widths, and rest 7 joints longer than wide. Relative lengths of joints from proximal to distal as 1.7: 1.2: 1.5: 1.3: 2: 1.5: 0.9: 0.9: 1. Each of them with short simple setae. Setal formula: I, 3; II, 14; III, 6; IV, 4; V, 4; VI, 3; VII, 2; VIII, 2; IX, 8.

Antenna (Fig. 1, F, G) 3-jointed. Ratios of lengths from the basal to the apical are 6: 5: 5. First joint with 2 long plumose setae at inner distal angle. Second with a short simple seta on outer face at distal one-third. Third with 2 short isolated setae and a group of 3 setae on outer face at the points 1/3, 1/2 and 3/4 away from its base. Claw slender, curved only at the apex and accompanied at the base by 3 stiff curved setae, 2 flexible shorter ones and a long stout plumose one.

Mandible (Fig. 1, H, I) composed of 2-jointed protopodite, 2-jointed endopod

Fig. 1, *Paranotodelphys villosus* n. sp., female. A, dorsal view; B, lateral view; C, urosome, ventral view; D, anal segment, dorsal view; E, antennule; F, antenna; G, apex of same; H, mandible; I, palp of same; J, maxillule; K, maxilla; L, maxilliped. A, B × 25; C × 50; D × 140; E, F. H × 185; G, I × 400; J, K, L × 270.

and 1-jointed exopod. Masticatory lamella of coxa cut from before backward into 1 acuminated and 3 blunt teeth, and a row of closely set denticles followed by 2 hairy setules. Basis carrying a plumose seta on inner margin near the distal one-

third. Basal joint of endopod furnished with 2 setae at inner distal angle and apical joint fringed by 8 setae at its apex. Exopod elongate and with 5 setae on inner and distal margins. Inner and outer faces of basis and exopod furnished with hairs.

Maxillule (Fig. 1, J) with 2-jointed protopodite and 1-jointed rami. Basal endite of coxa large and rimmed with 7 plumose setae and 2 setules on inner margin. Second endite terminating in a setiform elongation. At outer distal angle coxa has an epipodite which is represented by a long stout plumose seta associated with a short basal setule. Basis carries 1 long distal plumose and 1 short proximal setae on inner margin. Endopod is furnished with 2 short setae on inner margin and 3 long and 1 short setae at the apex. Exopod bears 4 long marginal setae.

Maxilla (Fig. 1, K) 5-jointed. Basal joint with 4 setiferous endites; first of these with 3 setae, 2nd with 1, 3rd with 2 and 4th with 2 setae and 1 tiny setule. Second joint produced medially into a long spine, which is associated at the base with a long seta. Third and 4th joints bear each a long inner seta. Fifth joint terminates in 3 feeble setae.

Maxilliped (Fig. 1, L) 3-jointed; first joint longest of all, attaining to about 2/3 of the total length, and provided with 9 inner setae forming distal group of 5 and proximal group of 4; second joint slightly shorter than half of the first and fringed by short hairs on inner margin in its proximal half; last joint very small armed with 2 subequal setae.

Four pairs of swimming legs gradually increasing in length from before backward and with distinctly 3-jointed rami. First swimming leg (Fig. 2, A) with intercoxal plate triangular in outline. Coxa with a long seta, reaching the end of 2nd endopod joint. Basis furnished at medio-distal corner with a stout spine extending to the end of 1st endopod joint, and on its short outer margin with a single plumose seta reaching the middle of 1st exopod joint. Endopod larger than exopod and with 8 setae; each of basal 2 joints with a single inner seta and 3rd joint with 3 inner, 2 apical and 1 outer setae. Exopod with 6 setae and 6 spines in all; each of proximal 2 joints with 1 inner seta and 1 outer spine, and 3rd joint with 3 inner and 1 terminal setae and 3 outer spines besides with 1 terminal spine, which is stoutest of all. All the spines (Fig. 2, B) pectinate on their borders and associated at the base with a tiny spinules.

Second swimming leg (Fig. 2, C) with rectangular intercoxal plate. Coxa has a relatively short medio-distal seta reaching the end of 1st endopod joint. Basis carrying a simple seta on outer margin. Endopod slightly shorter than exopod and furnished with 9 setae; 1st joint with 1 inner seta, 2nd with 2 inner setae and 3rd with 3 inner, 2 apical and 1 outer setae. Each of these joints with a short spinule at outer distal angle. Exopod has 7 setae and 6 spines; basal 2 joints bears each 1 outer spine and 1 inner seta; last joint is furnished with 4 inner and 1 apical setae as well as 1 apical and 3 outer spines. Every spine is associated at the base with a tiny spinule.

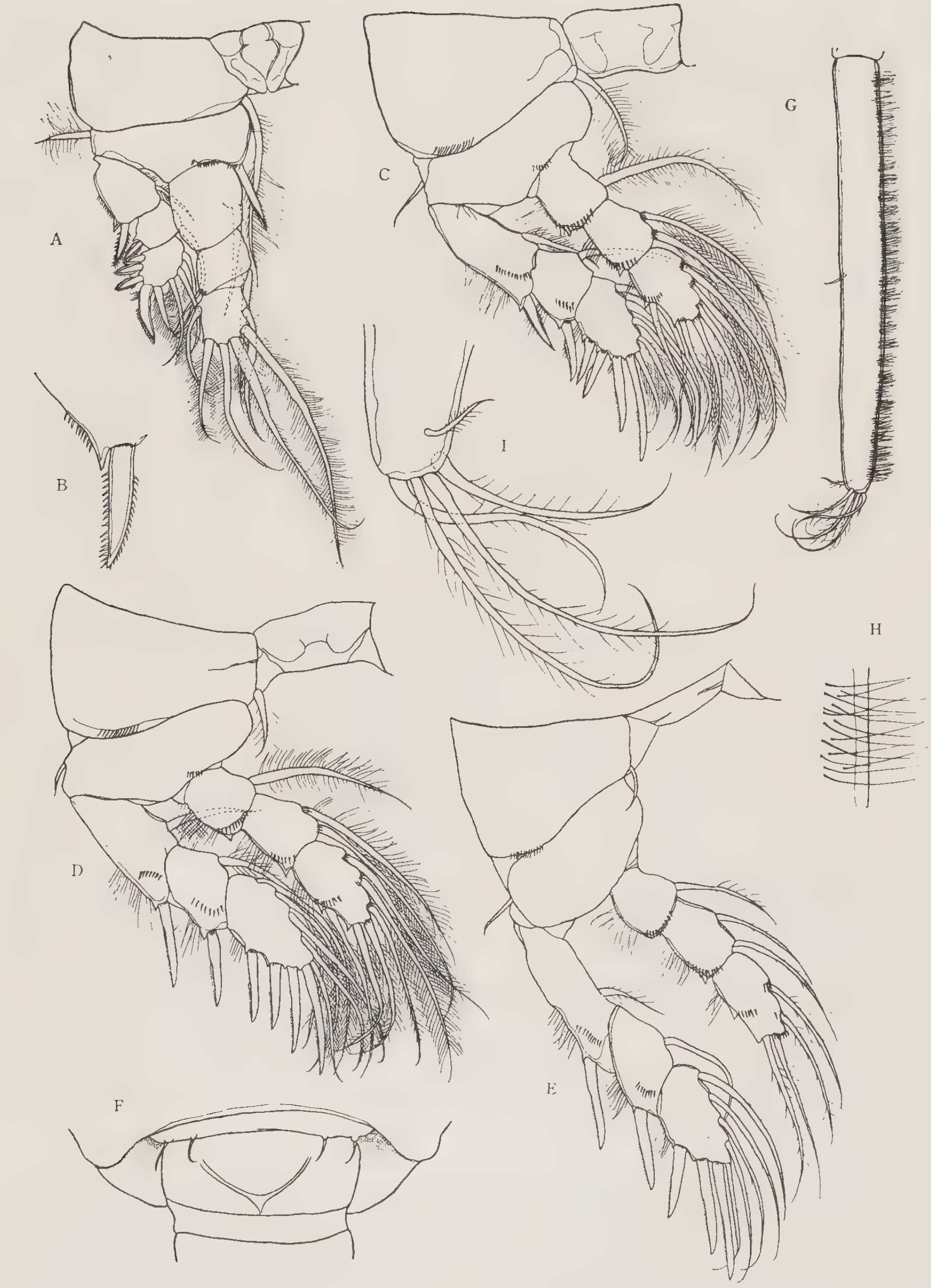

Fig. 2, *Paranotodelphys villosus* n. sp. A, 1st leg; B, same, spine of 1st exopod joint; C, 2nd leg; D, 3rd leg; E, 4th leg; F, 5th legs; G, caudal ramus; H, hairs on caudal ramus. A, C, D, E × 175; B, H, I × 400; F × 150; G × 100.

Third swimming leg (Fig. 2, D) resembles the 2nd in general constitution except for that coxal seta is far shorter than in the 2nd.

Fourth swimming leg (Fig. 2, E) conforms to the preceding, but the inner setae on the last endopod joint and the outer spines on the last exopod joint are smaller in number by one; inner seta of coxa is feeble and non-hairy, intercoxal plate is reduced, and the exopod is much longer than the endopod.

Fifth legs (Fig. 2, F) represented by 2 pairs of small bulges disposed side by side at the fore end of urosome and tipped by a short setule.

Caudal ramus (Fig. 2, G, H) elongate and slender, about 11 times as long as its greatest width and 3.8 times as long as anal segment. It bears 4 subequal terminal setae, a single outer seta at about the middle and a subterminal dorsal seta. Inner border of the ramus is thickly fringed by hairs which are divisible into numbers of groups of 15–20 hairs.

Male: Unrepresented in the present collection.

Remarks: Although the present form falls within the confine of the genus *Paranotodelphys* SHELLENBERG (1923) in its characters, it can not be assigned to any of the four known species on account of its slender body and long caudal furca. Above all, the most distinctive feature, by which it is easily recognizable, is the caudal furca which is thickly armed with hairs on the inner border.

Pachypygus globosus n. sp.

Occurrence: Five females were found in *Cnemidocarpa areolata* (HELLER) collected on January 26, 1961. The host examined was 5 in number, 4 of which contained 1 or 2 specimens. One of the females was found together with 2 specimens of *Doropygus* sp.

Female: Body (Fig. 3, A) reddish in color when alive, strongly dilated, curved ventrally and invested by heavily sclerotized integument with fine spinules on the surface. Anterior end of prosome in contact with ventral side of urosome, the body exhibiting a circular outline in profile. Prosome robust, short and ending in small triangular rostrum, which is bent ventrally at right angle. Metasome 4-segmented, tightly combined one with another; 2nd segment longest of all excluding the 4th forming brood sac, and the 3rd shortest. Urosome (Fig. 3, B) comprises 6 segments inclusive of 5th thoracic segment. Genital apparatus lies at anterior edge of 2nd urosomal segment. Proportional lengths of urosomal segments are 1: 3: 2: 1.3: 1.1: 1.1.

Antennule (Fig. 3, C) 6-jointed. Proximal 2 joints elongate and dilated. Proportional lengths of joints from the basal to the apical as 5: 6: 1: 1: 1: 2. Setal formula as I, 4; II, 26; III, 5; IV, 6; V, 4; VI, 11+1 aesthetask. All the setae non-hairy.

Antenna (Fig. 3, D, E) 3-jointed. Proportional lengths of joints from the basal to the apical are 7: 4: 6. Basal joint without seta. Second joint has a short seta on inner margin at a point 1/3 from its base and similar one on outer margin at 2/3. Third joint carries a group of 3 setae on outer margin 3/5 away from the

Fig. 3 *Pachypygus globosus* n. sp. A, lateral view; B, urosome, ventral view; C, antennule; D, antenna; E, same, apex; F, mandible; C, maxillule; H, maxilla; I, maxilliped. A × 25; B × 50; C × 170; D × 145; E × 300; F, G, H, 1 × 100.

base, and ends in a curved claw which is accompanied by 3 stiff basal setae as well as by a short inner distal row of spinules.

Mandible (Fig. 3, F) has coxa medially produced into a toothed masticatory lobe, and basis surmounted by 2-jointed endopod and 1-jointed exopod. Free border of masticatory lobe is cut into 5 teeth and truncate plate originating in the fusion of minor teeth, and furnished somewhat more proximally with 2 setules. Basis has a long plumose seta on inner margin. First endopod joint carries 4 short setae on inner margin, and 2nd joint bears an inner row of 4 short setae, distal row of 5 setae and a single outer seta located some distance apart from them. Exopod is suppressed, but has 5 long, stout, subequal marginal setae.

Maxillule (Fig. 3, G) composed of 2-jointed protopodite, 2-jointed endopod and 1-jointed exopod. Epipodite represented by a long at outer distal angle of coxa, and associated with a short basal setule. First coxal endite large and fringed with 9 setae and 1 setule on inner edge, and 2nd endite terminating in a setiform elongation. Basis furnished with 3 distal setae and 1 proximal setule on inner margin. Endopod bears 4 setae on median border of 1st joint and 3 on distal margin of 2nd joint. Exopod carries 4 rather long setae on terminal border.

Maxilla (Fig. 3, H) 5-jointed. Basal joint occupying more than half the entire length and with 4 setiferous endites; first of these with 4 setae, 2nd with 1, 3rd with 2, and 4th with 2 as well as with 1 tiny setule. Second joint is produced medially into a slender claw to whose base 2 long and short setae are inserted. Each of 3rd and 4th joints has a long seta at inner distal corner. Terminal joint is very small and armed with 4 slender apical setae.

Maxilliped (Fig. 3, I) well-developed and consisting of 3 setiferous joints; basal joint longer than wide, occupying about 2/3 of entire length, and furnished with proximal group of 4 setae and distal group of 5. Second joint with a single seta at the middle of inner margin. Third joint smallest and furnished with 4 apical setae.

First swimming leg (Fig. 4, A) with 2-jointed protopodite and 3-jointed rami. Protopodites of both sides connected with each other by a well-developed, trapezoid intercoxal plate. Plumose seta at the medio-distal corner of coxa reaching the end of 2nd endopod joint. Basis with a long, plumose outer seta, reaching the end of 1st exopod joint, and with a medio-distal spine. Endopod with 8 setae in all; 1 inner seta on each of first 2 joints, and 3 inner, 2 apical and 1 outer setae on terminal joint. Exopod with 6 spines and 6 setae; basal 2 joints each with 1 outer spine and 1 inner seta, and terminal joint with 3 outer, 1 apical spines as well as 1 apical and 3 inner setae. The apical spine longest of all, about 1.7 times as long as others.

Second swimming leg (Fig. 4, B) consisting of 2-jointed protopodite and 3-jointed flattened rami. Exopod longer than endopod. Intercoxal plate well-developed as in 1st leg. Inner coxal seta long and plumose as in 1st leg, but outer seta of basis short and non-plumose. Endopod with 9 setae; basal joint provided with one inner seta, 2nd joint with 2 inner setae, and 3rd joint with 3 inner, 2 apical and 1 outer setae. First to 3rd joints rimmed on outer side with delicate hairs. Exopod

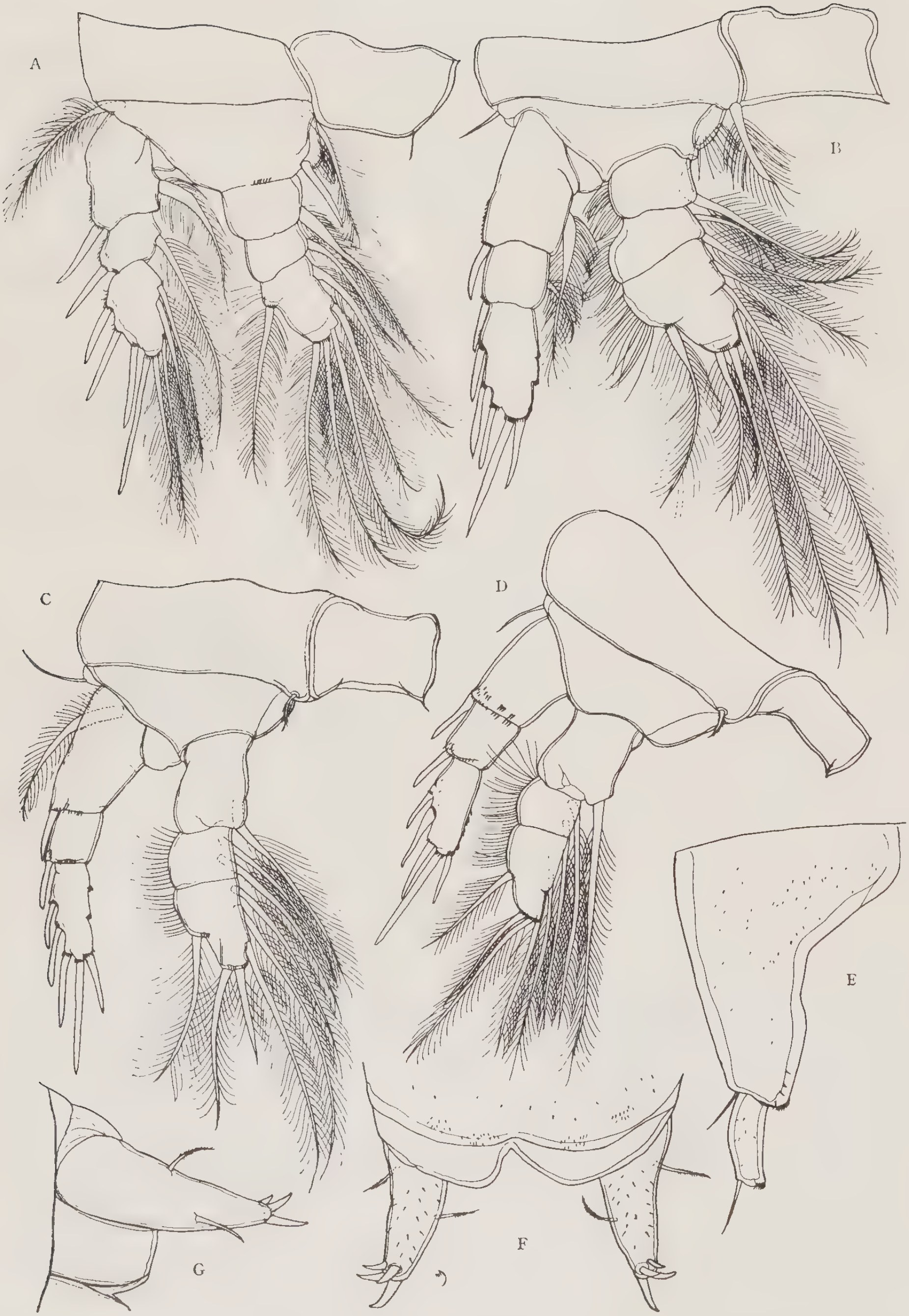

Fig. 4, *Pachypygus globosus* n. sp. A, 1st leg; B, 2nd leg; C, 3rd leg; D, 4th leg; E, 5th leg; F, caudal ramus; G, same, dorsal view. A, B, C, D, E × 100; F, G × 70.

modified, with most of the setae obliterated and replaced by tuft of fine spinules and armed with 7 spines and only 2 setae. Basal joint largest of all, with an outer distal spine, and with a long inner plumose seta at the middle of the joint. Second joint smallest of all and with a similar spine and an inner short, slender seta. Third joint with 5 spines; 3 on outer side and 2 at the apex; outer apical spine longest of all and almost twice as long as others. Setae on inner side of this joint absent and replaced by only tufts of fine spinules.

Third swimming leg (Fig. 4, C) is as in the 2nd except for that coxal seta is reduced to a setule and 2nd exopod joint has spine merely.

Fourth swimming (Fig. 4, D) leg has intercoxal plate much reduced as compared with those of preceding legs. Armatures of rami differ from those of 3rd leg in that the setae on terminal endopod joint is decreased by one in number and those on basal joint of exopod are lacking. Endopod has thus 8 setae and exopod 7 spines.

Fifth leg (Fig. 4, E) especially well sclerotized; basal joint long, broad at the base, narrow at the apex, and with a short non-hairy outer distal seta and a marginal row of short spinules at inner distal corner. Terminal joint reduced in size, about 1/3 as long as the basal, but with a similar armatures.

Caudal ramus (Fig. 4, F, G) somewhat unguiform and armed at its narrow tip with a stout spine as well as with 3 shorter spines. Outer margin with a short plumose seta about the middle and with another similar one on dorsal surface 1/3 proximad from the tip.

Male: Unrepresented in the present collection.

Remarks: The present species is a large-sized Notodelphyoid which is characterized by its expanded, circular body with a tough integument. Although such a peculiar appearance of the body is rather unusual to the genus *Pachypygus*, the anatomical features of all the appendages definitely show its affinity to the known species of the genus. This apecies can be distinguished from the known species by the 2nd to 4th legs having the exopod armed with 7 spines instead of 6 as in the latter.

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Studies on Vitamin B_6 in Marine Products IV.

The Distribution of Vitamin B_6 in Seaweeds

(With 2 Figures and 3 Tables)

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Many investigations have been made on the distribution of vitamin B group in marine algaes (Nitta et al, 1948; Fujita, 1948; Tanaka, 1055; Murayama and Tabei, 1956; Sabashi, 1956; Teeri and Bieber, 1958; Kanazawa and Kakimoto, 1958; Mita, 1960; Kanazawa, 1963) and some authors have suggested that seaweeds are important as a source of vitamin B group. But B_6 contents and distributions of many species of marine algaes have not been known as yet and it is interesting to study the biochemical and physiological functions of B_6 in them.

This paper deals with the distribution of B_6 in both the fresh weeds which are taken easily at the seaside and the commercial edible products using the microbiological method, and also the comparison with that of aquatic animals.

Experiments

Fresh samples used for assay were collected in Ise Bay, chiefly Tsu, Toba, and Hamajima coasts, and were brought to the laboratory in the dark box as soon as possible after gathering. This sampling was carried out during the period from July, 1956 through February, 1960. The commercial edible products were obtained at the grocery shops in Tsu city.

B_6 was determined with the yeast *Saccharomyces carlsbergensis* No. 4228 as described in the previous report (Miyake and Hayashi, 1954).

For extraction of B_6 from samples, 100 ml. of 0.055N H_2SO_4 was added to 2–3 g of small pieced fresh weed, and 100 ml. of 2N H_2SO_4 to 1–2 g of weed product, and then they were hydrolyzed at 20 pounds of pressure for two and half hours.

In this print B_6 content was expressed as pyridoxine considering the report of Rabinowitz and Snell (1948), who identified the pyridoxine as a principal constituent of B_6 group in the plant. The results obtained are shown with the average values in four years.

Results and Discussion

Extraction of B_6 from seaweeds.

Since it has been known that the greater part of B_6 exists in combined forms with proteins or other substances in living things, it is necessary to hydrolyze tissues with various acids and to liberate as free B_6 forms for the microbiological determination of B_6. RABINOWITZ and SNELL (1947) noted that the highest value was obtained by treating with 2N H_2SO_4 to the vegetative tissue, and with 0.055N H_2SO_4 to the animal tissue, at 20 pounds. But an optimal condition for B_6 extraction from seaweeds has not been decided yet, the experiment was carried out to determine the optimal condition of hydrolysis. The rate of release of B_6 was observed in every hour until five hours with a few seaweed samples. The results are shown in Fig. 1 and 2.

More increased B_6 liberation from seaweed products (dried seaweeds), showing with Asakusanori (*Porphyra tenera*) and Kajime (*Echlonia cava*), was observed by 2N than by 0.055N H_2SO_4. It may be due to the difficulty of B_6 extraction from tough dried tissues, as it was seen from the fact that the seaweed products can keep their original shape during five hours hydrolysis with 0.055N H_2SO_4 at 20 pounds.

There was, however, no difference in B_6 extraction from fresh seaweeds between 2 and 0.055N H_2SO_4. This must be due to the softness of their fresh tissues.

Maximal B_6 yields for both dried and fresh weeds were observed during two to three hours hydrolytic treatment, as shown in Fig. 1 and 2. Configuration of the eight curves obtained in this experiment was almost similar: maximal B_6

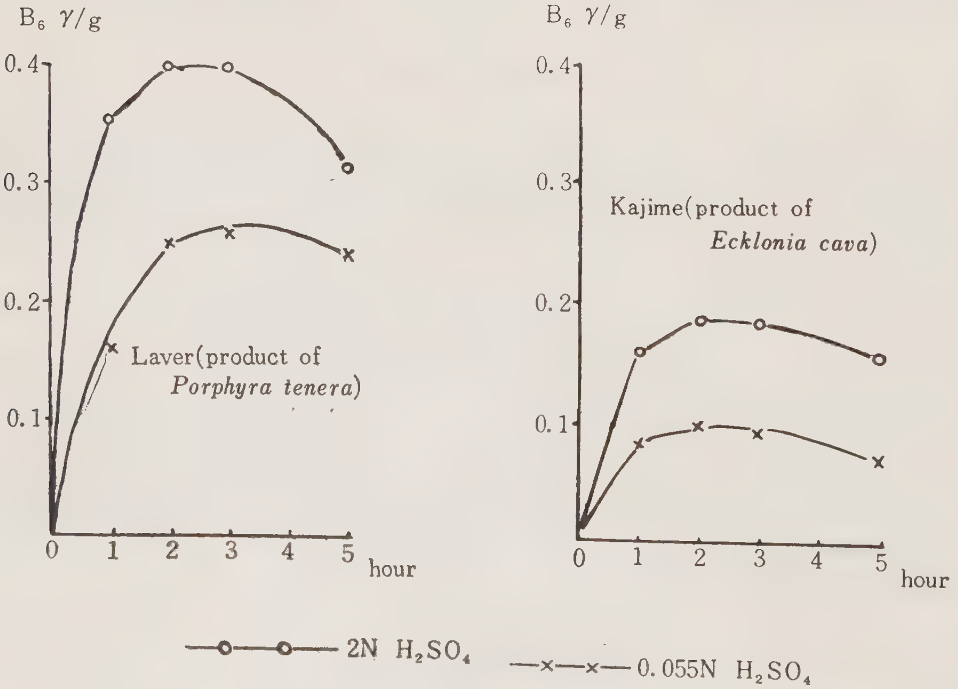

Fig. 1. Liberation of B_6 from dried seaweed products by acid at 20 pounds of pressure.

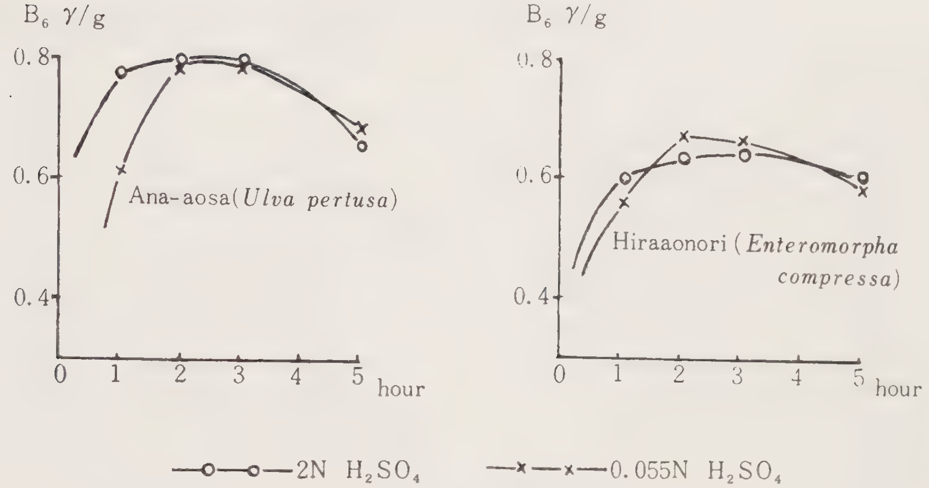

Fig. 2. Liberation of B_6 from fresh seaweed by acid at 20 pounds of pressure.

extraction was followed by gradual decrease with the lapse of hydrolyzation time. It has been considered that B_6-complexes are decomposed into free B_6 and other constituent small molecular substances by acid hydrolysis without changing B_6 form or being destroyed (Eakin et al, 1950). From the above results, however, it is clear that B_6 extracted from the samples, will be incativated gradually by prolonged acid hydrolysis.

Consequently, the following conditions were used for proceeding the experiment: two and half hours hydrolysis with 2N H_2SO_4 seaweed products, and with 2 or 0.055N H_2SO_4 for fresh seaweeds, at 20 pounds of pressure.

B_6 contents of various seaweed products.

Table 1. gives B_6 contents of various seaweed products. A small amount of B_6 was found in sea weed products obtained from commercial sources with exception of lavers (products of *Porphyra tenera*). Comparing B_6 contents of these seaweed products with those of fresh weeds (Table 2 and 3), and animal and plant tissues (Rabinowitz and Snell, 1948; Miyake nad Hayashi, 1956; Yanase, 1956; Sabashi, 1956; Kanazawa, 1963), it might be concluded that these seaweed products are poor B_6 sources from a nutritional standpoint, except laver and seasoned lavers.

Rapid destruction of B_6 group under ultraviolet light has been indicated by Sakurai (1952) and Sabashi (1956). Accordingly, this small amount of B_6 might be the result of B_6 destruction during the process of manufacturing, especially drying by sunlight.

Agar is made from Makusa (*Geridium amansii*) and other red algaes. The agar sample obtained from commercial origin for bacteriological media, contained only 3. 8 γ/100 g of B_6 on dry basis, while that of fresh Makusa was 257 γ/100 g (Table 2). These results indicate that the greater part of B_6 in raw seaweed is lost in the

Table 1. B_6 Contents of Seaweed Products.

Sample		Moisture %	B_6 γ/100 g	
			In fresh matter	In dry matter
Ma-konbu	*Laminaria japonica* ARESCH.	25.1	6.9	9.2
Oboro-konbu	*Kjellmaniella gurata* MIYABE.	28.5	3.7	5.2
Aokiri-konbu	*Laminaria japonica* ARESCH.	33.7	4.5	6.8
Wakame	*Undaria pinnatifida* (HARV.) SURING.	28.0	6.3	8.8
Arame	*Eisenia bicyclis* (KJELLM.) SETCH.	6.2	3.9	4.2
Fukuro-funori	*Gloiopeltis furcata* POST. et RUPR.	20.2	3.0	3.8
Kajime	*Ecklonia cava* KJELLM.	16.9	18.5	22.3
Agar	*Gelidium amansii* LUMX.	22.0	2.9	3.7
Laver	*Porphyra tenera* KJELLM.	10.3	68.2	76.0
Seasoned laver				
First class	〃	17.3	71.7	86.7
Second class	〃	21.8	39.9	51.0
Third class	〃	21.1	15.4	19.5

manufacturing process.

Among the seaweed products examined, seasoned lavers contained much B_6 (19.5—86.7 γ/100 g). But this may be attributed partly to B_6 included in soy sauce and other taste-flavor materials which were added to lavers for their seasoning. It is an interesting fact that their commercial prices and B_6 contents have a proportional relationship.

B_6 contents of fresh seaweeds.

B_6 occurrence in seaweeds may be varied according to species, parts of weed, age, growing places, changes of growing environment, season, and their freshness etc. These factors should be considered in the determination of B_6 contents of various seaweeds.

Fresh seaweed samples were collected during summer (June and July) and winter (January and February) seasones. The analytical results were averaged from those of more than five samples. The results are summerized in Table 2 and 3.

No clear characteristic tendency was observed on B_6 distribution among red, green, and brown-color algaes, but brown algaes showed rather a small amount of B_6 in both winter and summer samples.

Winter samples contained more B_6 (21—1224 γ/100 g) than that of summer samples (7—870 γ/100 g), as seen in Table 2 and 3. This seasonal difference may be the reflection of two factores; nutritional change, and degree of solar irradiation. High B_6 level in winter samples may be brought about by better nutritions in sea water and weak sunlight in winter time.

Young Umitoranoo (*Sargassum thunbergii*) contained 82 γ of B_6, but the old differ-

Table 2. B_6 Contents of Fresh Seaweeds (Summer Samples).

Sample		Moisture %	B_6 γ/100 g	
			In fresh matter	In dry matter
(Red seaweed)				
Makusa	*Geridium amansii* Lumx.	65.3	89	257
Matsunori	*Carpopeltis affinis* (Harv.) Okam.	70.7	51	174
Shikinnori	*Gigartina teedii* (Roth) Lamour.	86.1	50	360
Ibaranori	*Hypnea seticulosa* J. Ag. var.	86.4	46	340
Nise-fusanori	*Gloiophloea okamurae* Setch.	87.6	15	121
Kaninote	*Amphiroa dilatata* Lumx.	36.0	10	15
Fusa-kaninote	*Amphiroa aberrans* Yendo	28.0	25	35
Tsunomata	*Chondrus ocellatus* Holmes	78.8	19	93
Mitsude-sozo	*Laurencia okamurai* Yamada	84.5	39	252
Okitsunori	*Gymnogongrus flabelliformis* Harvey	75.1	25	100
Naminohana	*Chondrococus japonicus* (Harv.) Okamurai	87.0	17	132
Tanbanori	*Grateloupia elliptica* Holmes.	89.2	7	65
Matobo	*Polyopes polyideoides* Okamura	68.8	61	204
Watsunagiso	*Champia parvura* (Ag.) J. Agardh	91.7	15	189
Obakusa	*Pterocladia tenuis* Okamura	80.6	36	186
Sakuranori	*Grateloupia imbricata* Holmes	70.2	36	152
Hai-tengusa	*Gelidium pusillum* (Stack.) LeJolis	90.1	72	726
Onikusa	*Gelidium japonicum* Okamura	68.8	52	169
Yukari	*Plocamium telfairiae* Harvey	88.2	52	448
(Green seaweed)				
Hoso-jujumo	*Chaetomorpha crassa* (Ag.) Kutz.	89.1	13	120
Naga-miru	*Codium cylindricum* Holm.	92.1	29	404
Kobushi-miru	*Codium pungniformis* Okam.	96.6	5	149
Uchiwa-sabotengusa	*Halimeda cuneata* Hering	85.7	18	126
Ana-aosa	*Ulva pertusa* Kjellm.	89.1	84	870
Hira-aonori	*Enteromorpha compressa* (L.) Grev.	91.4	70	820
Miru	*Codium fragile* (Suringar) Hariot	94.6	9	177
(Brown seaweed)				
Ishige	*Ishige okamurai* Yendo	65.7	32	96
Oobamoku	*Sargassum ringgoldianum* Harv.	82.4	27	154
Isomoku	*Sargassum hemiphyllum* C. Ag.	84.0	31	193
Narasamo	*Sargassum nigrifolium* Yendo	84.8	16	108
Togemoku	*Sargassum microcanthum* (Kutz) Yendo	76.7	12	51
Yoremoku	*Sargassum tortile* C. Ag.	82.8	41	238
Arame	*Eisenia bicyclis* (Kjellm.) Setch.	76.9	14	60
Umitoranoo (young)	*Sargassum thunbergii* (Mert.) O. Kuntze	83.0	14	82
Umitoranoo (old)	//	73.9	2	7
Umiuchiwa	*Padina arborescens* Holmes	81.0	7	37
Yatsumatamoku	*Sargassum patens* C. Agardh	80.8	9	51

Table 2 Continued

Hondawara	*Sargassum* sp.	76.7	12	52
Iwahige	*Myelophycus caespitosus* (HARV.) KJELLM.	80.5	41	210
Hera-yahazu	*Dictyopteris prolifera* (OKAMURA) OKAMURA	73.3	10	37

Table 3. B_6 Contents of Fresh Seaweeds (Winter Samples)

Sample		Moisture %	B_6 γ/100 g	
			In fresh matter	In dry matter
(Red seaweed)				
Ogonori	*Gracilaria verrucosa* (HUDSON) PAPENFUSS	89.5	93	892
Asakusanori	*Porphyra tenera* KJELLM.	89.5	128	1224
(Green seaweed)				
Ana-aosa	*Ulva pertusa* KJELLM.	84.1	138	871
Usuba-aonori	*Enteromorpha linza* (LINNE) J. AGARDH	86.8	121	925
Hitoegusa	*Monostrima nitidum* WITTROCK	87.5	120	960
(Brown seaweed)				
Habanori	*Endarachne binghamiae* J. AGARDH	68.7	6	21
Shiomidoro	*Ectocarpus* sp.	92.4	36	479

ent strain showed only 7 γ. This is an example to show the variations of B_6 contents in different aged algaes.

Comparing the above estimated B_6 values with those of other tissues of living things, it is obvious that the amount of B_6 in seaweeds was not larger than other tissues, but they should not be disregarded as a B_6 source, particularly, edible winter seaweeds.

B_6 biosynthesis by marine bacteria was reported by author (1955). It may be considered that B_6 produced by bacteria living on the surface of algaes, is involved in the analytical result. This may be avoided by washing fresh weeds carefully with sea water in the sampling.

B_6 group in Asakusanori was described by SABASHI et al (1956) as follows: pyridoxine 1.80 γ/g, pyridoxal 6.40 γ/g, and pyridoxamine 2.20 γ/g. Pyridoxal was a principal type of B_6 group in seaweeds in his single result. The later investigation will show the distribution of B_6 group in marine algaes.

Summary

1) Total amounts of B_6 in commercial seaweed products and fresh seaweeds were estimated by the microbiological method.

2) The optimal hydrolysis conditions of B_6 extraction from samples were: 2N H_2SO_4 for weed products, 2 or 0.055N H_2SO_4 for fresh weeds, at 20 pounds of pressure for two and half hours.

3) A small amount of B_6 was found in seaweed products ($3.7-22.3\,\gamma/100$ g on dry basis) except laver and seasoned lavers ($19.5-86.7\,\gamma/100$ g on dry basis).

4) Fresh seaweeds collected in winter season showed higher B_6 contents than those of summer seaweeds.

5) Although B_6 contents of seaweeds are not larger than those of animal and plant tissues, they should not be disragarded as a B_6 source, especially edible winter weeds.

The author's many and hearty thanks are due to Mr. W. KIDA of Marine Algae Laboratory of this Faculty for his helpful advices and the assistance of the identification of the seaweeds. The encouragement and support of Professor M. MIYAKE of this Faculty are gratefully acknowledged.

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Tanaidacea collected by Naga Expedition in the Bay of Nha-Trang, South Viet-Nam

Sueo M. SHIINO

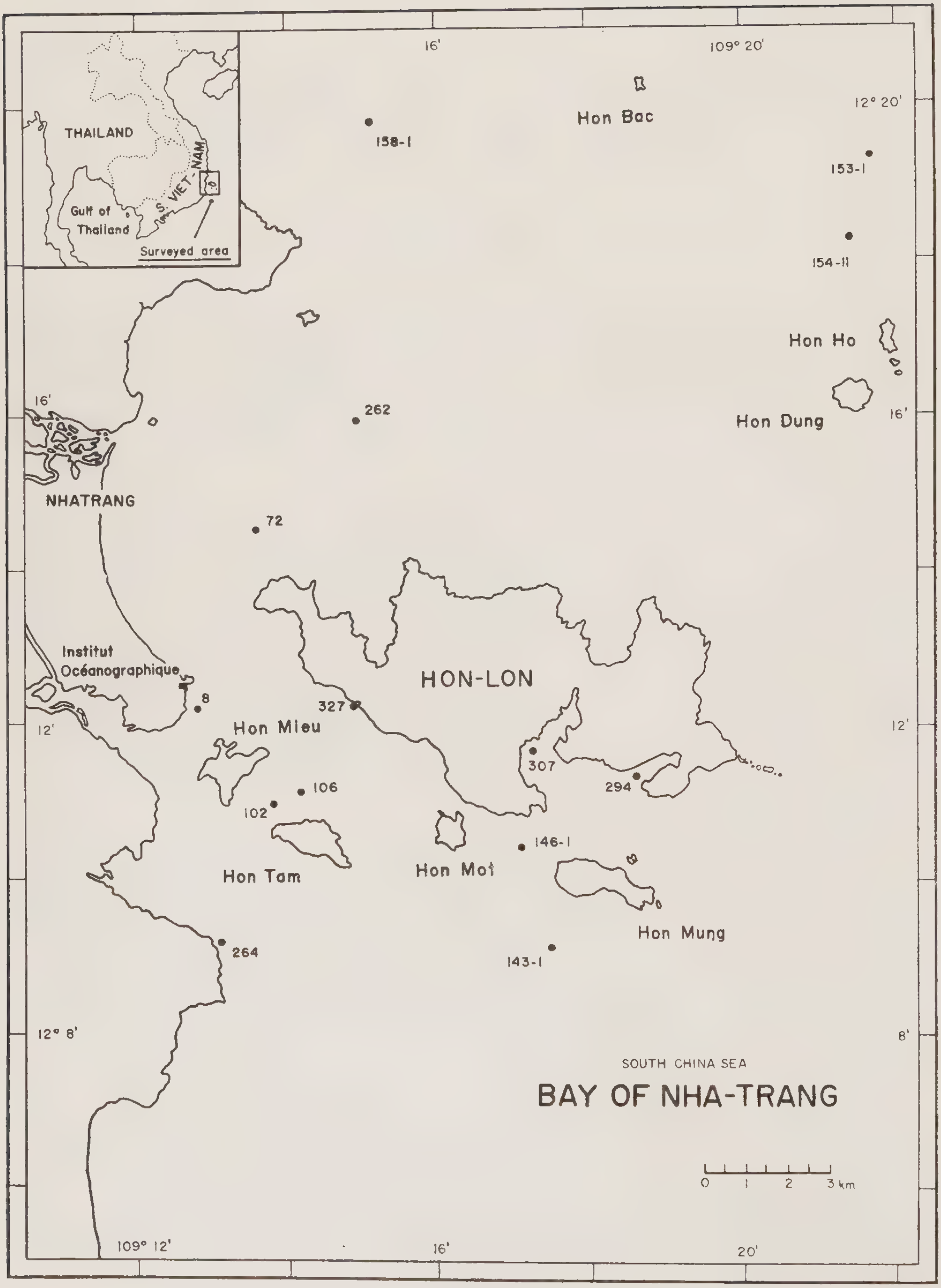
(With 1 Map and 25 Text-figures)

During the last twenty years our knowledge on the Tanaidacea of the world was increased to a great extent. We owe this to the excellent works of the authorities, such as K. LANG, M. BĂCESCU, T. WOLFF, R. J. MENZIES and so on. As to the tanaidacean fauna in the Indo-Pacific Region, a large number of species have been published chiefly from the waters of India and Ceylon, but little has been known from the coasts of the South China Sea.

At the end of 1959, Dr. V. A. GALLARDO, who was in the Central Biological Institute, University of Conception in Chile as a young promissing investigator, got an extraordinary opportunity of visiting South Viet-Nam for making the ecological study of the bottom fauna in Oceanographical Institute at Nha-Trang. During three months beginning from January, 1960, as a member of the "Naga" Expedition from the University of California, he carried out a continuous sampling of the bottom fauna in the Bay of Nha-Trang and its neighborhood, using the quantitative bottom samplers of PETERSON and VAN VEEN type 0.1 m^2. The stations worked out by him were 340, covering all types of the bottom ranging from 3 m to 50 m, and the samples obtained amounted to 450.

Afterwards, when he was staying in the Marine Biological Laboratory of the University of Copenhagen in Helsingør, Denmark in order to ellaborate his material, he made contact with me, asking for my help in the identification of the Tanaidacea which he picked out from his collection in Nha-Trang. Seizing this excellent opportunity afforded by him, I consented to his request, and received from him the materials preserved in more than 20 vials. Although the study on his very interesting collection was finished much earlier than this, I have had no proper chance of publishing the results for various reasons.

The results of my study yielded seven species, six of these belonging to the Family Apseudidae and the rest to the Family Paratanaidae. As is to be expected in the case of the benthic fauna which leaves much to be made out, the species found in the Bay of Nha-Trang were all new to science and one of them represented even a new genus. One thing to be emphasized is the blindness of all the representatives of Apseudidae in the present collection. They are for the greater part entirely lacking also in melanophores on their bodies. Without doubt, these may have arisen from their subterranean mode of life. The name of the species together



Map 1. The Bay of Nha-Trang, South Viet-Nam, showing the stations at which the specimens of Tanaidacea were obtained.

with the stations at which they were obtained are listed below. The locations of the stations within the Bay are shown in Map 1. The specimens will be preserved in the Prefectural University of Mie hereafter.

Apseudes nhatrangensis sp. nov. Stations: 143 I, 153 I, 154 II, 351, 355.
Apseudes nagae sp. nov. Station: 297.
Apseudes gallardoi sp. nov. Stations: 72, 262, 264.
Apseudes tenuicorporeus sp. nov. Stations: 146 I, 158 I, 264.
Apseudes nigrifrons sp. nov. Stations: 146 I, 297.
Pagurapseudopsis gracilipes gen. et sp. nov. Stations: 8, 102, 106 II.
Leptochelia longimana sp. nov. Stations: 294, 308, 327.

It is my pleasure to record here a debt of gratitude to Dr. V. A. Gallardo, now in Allan Hancock Foundation, University of California in Los Angeles, for his kindness in offering me a good chance of studying his very interesting collection.

Family Apseudidae

Apseudes nhatrangensis sp. nov.
(Figs. 1–4)

Occurrence: Station 143 I, depth 38 m, mud bottom, at 10: 40, on February 23, 1960. One female 9.9 mm long. Station 153 I, depth 43 m, at 9: 35, on February 24, 1960. One female 9.6 mm long. Station 154 II, depth 43 m, at 10: 05, on February 24, 1960. One female 9.8 mm long. Station 351, no datum. One female. Station 355, no datum. One female. The female from Station 154 II was dissected.

Female: The body is slenderly elongate, depressed, and widest in the carapace from which it tapers backward only slightly. 9.6 mm × 1.6 mm. Color is yellowish white in alcohol, without pigmentation.

The carapace is about as long as wide, a little longer than the first two peraeomeres combined together and wider than any of the succeeding somites. It is more or less quadrangular in shape, but has the fore margin arched in a V-shape. The rostrum is conical, ending in a short spine somewhat bent downward, and is expanded at the base into a pair of small blunt lateral lobes lying above the antennule. It bears a few short hairs on the dorsal surface. Each antero-lateral angle of the carapace is produced forward into a stout, sharply pointed, spiniform process, which reaches the level with the lateral lobes of the rostral base and carries a few short plumose hairs on the lateral border. The ocular lobe is short, wider outward than inward, somewhat undulated on the fore margin, and is inserted in the sinus between the antero-lateral process and the rostral base. The visual elements and pigment are missing. The sides of the carapace are almost parallel and notched at the bases of the antero-lateral processes, behind which those are slightly bulged outward. The dorsal face of the carapace is traversed by shallow but distinct grooves. The cervical groove which combines those notches of the sides is sinuous,

curving backward in the median region, in which it is interrupted for a short distance. A pair of short longitudinal grooves arise from the rostral base and run backward on either side of the midline for a short distance. A pair of oblique grooves starting from the inner sides of the antero-lateral spines extend toward the cervical groove, without reaching this. Another oblique pair arising from the central part of the cervical groove is directed postero-externally as far near as the hind corners of the carapace. The clypeus bears a sharp, anteriorly directing, central spine which is far stouter than the rostral spine. The sternum of the cephalothorax is armed in the region just behind the maxillipeds with a medio-ventral spine turned forward.

The thorax occupies a half of the entire length. Of six peraeomeres, the first is in close contact with the carapace, whereas the succeeding five are more loosely connected with the adjoining peraeomeres and discontinuous on the sides. They are slightly but successively decreasing in width from before backward. The first two peraeomeres are subequal in length, the following three are longer but subequal to one another, and the last is again shorter and about as long as the first.

The first peraeomere is a little expanded laterally into widely round lobes and carries a narrow marginal lamella on either side, occupying the anterior half of the margin. Two pairs of longitudinal surface grooves are discernible, the inner pair being more or less sinuous. The coxal plate present at each antero-lateral angle of this segment is a stout, triangular, antero-laterally pointing structure with a few plumose setae on the inner side. The segment is armed with a posteriorly turning median spine on the sternum.

The second peraeomere is somewhat directed backward in its well round lateral areas, and has longitudinal surface grooves which are combined together by two horizontal grooves. The marginal lamella occupies entire lateral border and is lacking the coxal plate. The medio-sternal spine is bent forward.

The succeeding four peraeomeres are similar to one another in their constitution. Their lateral borders bear near the anterior angles a sharp, forwardly directed, curved process, behind which they are marginated by a lamella broader than in the first two peraeomeres. The lamella is produced into a small pointed process in the fifth peraeomere at the posterior angle. The coxal plate is a crescentic lobe present laterally to the marginal lamella and is distinct in the last three peraeomeres, but absent from the third. The surface grooves are more or less similar in these peraeomeres and consist of a pair of internally arched grooves extending from the antero-lateral angles of the segment to the postero-lateral angles, another pair of further lateral, oblique ones, and two short mid-dorsal transverse grooves combining the members of the former pair. The mid-ventral spine of the third peraeomere is turned backward, whereas that of the last three is directed forward and bent at right angles at the apex. The spine of the last peraeomere is the stoutest of all.

All the peraeomeres are fringed along lateral borders by short hairs which are simple or plumose in nature. Oostegites are four pairs of small narrow oval lobes

Fig. 1. *Apseudes nhatrangensis* sp. nov., female. A, female, dorsal view; B, cephalothorax, ventral view; C, antennule (left), ventral side; D, antenna (left), ventral side; E, labrum; F, mandible (left), outer view; G, same, posterior view; H, incisor process of left mandible; I, same of right mandible; J, right half of labium. A × 13, B × 27, C, D × 41, E–G, J × 83, H, I × 170.

present in the first to the fourth peraeomeres.

The abdomen is one third as long as the entire body and composed of five short pleomeres and long pleotelson. The pleomeres are equal in size and structure to one another, and have the width equal to that of the last peraeomere inclusive of the coxal plates and the length occupying more than half of the whole abdomen. They are transversely linear, their lateral parts acuminating toward the sides, which terminate in a sharp, posteriorly turning spine. The lateral parts are heavily setose both on anterior and posterior borders, and carrying an additional transverse dorsal row of hairs. The first two pleomeres are provided on the sternum with a small, low, median tubercle which becomes indistinct from the third backward.

The pleotelson is about two thirds as long as the preceding pleomeres combined together, half as wide as these, elongate quadrangular in shape, terminating caudad in a V-shape, and is produced at each caudo-lateral angle into a small triangular bulge to receive the base of uropod. It is circumscribed by setae all around its free border and beset with several transverse rows of short hairs on the dorsal surface.

Antennule is longer than the carapace, consisting of three-jointed peduncle and two flagella. The first peduncular joint is longer than the other two joints combined together, broadest of all, and two and a half times as long as the second joint, which is longer than twice of the third. All the joints are fringed on the inner border with series of plumose setae and surrounded around the distal border with a ring of similar setae; the outer border of the first joint bears setae somewhat irregularly disposed. The inner flagellum is shorter than the outer flagellum, which is also shorter than the peduncle, and is 9-jointed; the peduncle is 13-jointed, arising from the outer depression of the first joint of the former. Each joint of the flagella is sparingly setose at the end. The setae are assorted into two kinds, one simple and short, and the other longer, thicker and sensory in function.

Antenna is shorter than the antennule, reaching the second peduncular joint of the latter. The peduncle is two-jointed, the exopodite is one-jointed and squamiform, and the endopodite is elongate, consisting of 13 joints. The first joint of the peduncle is short, produced inward into a triangular bulge and non-hairy. The second joint is longer, fringed by plumose setae on the inner side and carries at the outer distal angle a short narrow exopodite circumscribed by long plumose setae. The first endopodite joint is short and bears a single plumose inner hair. The second and third joints are far longer than the other joints, subequal to each other, and provided only with simple hairs. The fourth and fifth joints bear long plumose as well as short simple hairs. The rest joints have either simple hairs only, or none.

Labrum, trapezoid in shape, is truncated on free margin and finely serrated on the lateral borders in their proximal halves. It bears a bundle of stiff hairs on

Fig. 2. *Apseudes nhatrangensis* sp. nov., female. A, left half of body, dorsal view; B, thorax, lateral view; C, maxillula (left); D, basis endite of left maxillula; E, precoxal endite of same; F, maxilla (left); G, spines on the coxal endite of maxilla; H, maxilliped (left), external view; I, same, internal view; J, epipodite of maxilliped. A, B × 19, C, H–J × 83, D, E, G × 340, F × 120.

either side just distally to the marginal serration.

Labium is a broad lamella with a median incision and carries at the outer distal angles a crescentic accessory lobe, which is marginated by a row of hairs and ends in three spines.

Mandible has three-jointed palp. Both incisor and molar processes are elongate, rod-like structures which make a right angle with each other. The incisor process is cut into four denticles on the right mandible, and into five on the left member, which is accompanied at the base of the denticles by lacinia mobilis terminating in four teeth. Accessory spines are six or seven in number and either forked, or finely serrated at their expanded apices, or finely pectinate along their axes. The molar process is somewhat depressed at the end and thickly beset with fine denticles. The first joint of the palp is furnished with a few long plumose setae on the inner border. The second joint carries double row of short stiff hairs in its apical half and a rather long terminal seta. The third joint is thickly bordered by a single row of stiff short hairs and ends in two very long setae. The setae on the apical two joints are simple in structure.

Maxillula has two-jointed, backwardly directing epipodite. The coxal endite is tipped by five recurved spines with single or double row of fine hairs in their apical portion; the central spine is bifid and heavily surrounded by fine hairs on all side. The endite of basis ends in eleven stout blunt spines and carries two, sharply pointed, subterminal spines which are doubly edged by fine cirri. Both the endites are hairy on the outer and inner borders. The first epipodite joint is longer than the second joint which is fringed in the terminal portion by nine hairs graded in length; all the hairs are finely ciliated near the apices.

Maxilla is a triangular lamella. The coxa is heavily armed on the inner margin with stiff setae and bears two longer plumose setae at the proximal end as well as another similar seta at the distal end. The coxal endite is marginated by four proximal spines and distal row of stiff setae. Of these spines, the proximalmost is longer than others and expanded at the apex like a spatel surrounded by serration; the rest spines are forked into three or four short branches and are associated with a plumose spine inserted between them and the setae row. The first endite of the basis carries two isolated proximal spines and a distal row of simple, recurved setae. The second endite bears eight long stiff setae which are doubly edged with fine hairs in the basal portion and pectinate in the apical portion.

Maxilliped has four-jointed palp and the epipodite broadely expanded at the apex. The coxa is quadrate, terminating in a broad endite with well round outer margin. The inner border of the coxa bears a row of plumose spines and four retinacula, and the outer border is finely ciliated; the terminal border of the endite has stouter setae. The first joint of the palp is short, slightly expanded outward and sparingly setose. The second joint is longest and broadest of all, produced laterally into a linguiform lamella, and, extending from the base of the inner border to the extreme outer angle of the distal border, it is thickly beset with long margi-

nal setae. The setae are for the greater part simple, but are mingled with a few elongate plumose ones on the inner border of the joint as well as at the outer distal angle. The third joint is much smaller than the second, but is expanded inward

Fig. 3. *Apseudes nhatrangensis* sp. nov., female. A, cheliped (left), external view; B, chela (right cheliped), internal view; C, exopodite of left cheliped, external view; D, 1st peraeopod (left), external view; E, merus of 1st peraeopod (right), internal view; F, exopodite of 1st peraeopod (left), external view; G, 1st pleopod (left), anterior view; H, same, posterior view. A, D, E, G × 41, B × 83, C, F × 120, H × 52.

into a rounded lobe which is thickly marginated by an external row of very long stiff setae and an internal row of short hairs. The apical joint is narrow, and surmounted by a bundle of long stiff setae at its truncate end. The epipodite is a broad, quadrate, cup-like lamella, and carries a small quadrate inner lamella ciliated on the margin, and a styliform outer lobe doubly edged with setae in the apical part.

Cheliped is relatively slender, held parallel to the body, and consists of five joints, the terminal two of which form a chela, and the two-jointed rudiment of exopodite. The basi-ischium is narrowed toward the base, and bears a stout spiniform process on the outer margin at about the middle, three short scattering hairs behind this and a bundle of short hairs at the outer distal angle. The merus, making an obtuse angle with the basi-ischium, is narrower than this and bears a spiniform process at the end of the ventral border, on which the joint is furnished with long simple or plumose setae. The joint is also armed with subterminal transverse row of setae on the inner face. The carpus is broader and longer than the preceding joint, to the dorsal border of which it is attached and disposed almost parallel. The ventral border of the carpus is more or less serrated and bears five elongate plumose setae besides far shorter simple ones. The dorsal border is almost destitute of hairs except for having a terminal group of short hairs. The propus is about as long as the carpus with which it makes a right angle. The hand is about as broad as the carpus, half as long as the entire propus, and well curved at the dorso-proximal angle. It has solitary plumose hairs on the outer border about the middle, a subterminal transverse row of long stiff hairs, intermingled with shorter plumose ones, on the inner face, and a few stiff terminal setae on the outer face. The terminal finger is slightly recurved, attenuated toward the tip which ends in a claw. It bears on the inner border about the middle a triangular prominent process, beyond which the border is indistinctly serrated and fringed by a series of short hairs; the ventral border is furnished with a row of much longer setae; the inner surface bears a few setae near the base as well as at about the middle of the entire length. The dactylus is somewhat narrower than the finger of the propus, widely curved ending in a stout claw, and is supplied with a few subterminal setae besides with a solitary one on the dorsal border. The exopodite is two-jointed; the apical joint is shorter than the basal and tipped by four plumose setae.

The first peraeopod is fossorial, having joints flattened and broader than those of the succeeding legs, and is geniculated between the ischium and the merus. The basis is the longest of all the joints, and is armed with a stout spiniform process on the ventral border at about its proximal one-third, beyond which the border is sparingly setose. At the ventro-lateral angle, the joint carries a stout spine and a few setae. The ischium is very short, bearing a bundle of short hairs at the ventral angle besides a solitary one at the dorsal angle. The merus is broader distally than proximally, armed with a stout dorso-distal spine, and plentifully supplied

with long hairs which are arranged in three longitudinal or oblique rows, one extending along the distal half of the ventral border, another being subterminal oblique row on the inner face, and another being terminal oblique one on the outer face. The carpus is broader but shorter than the merus and is armed with two dorso-distal spines and two rows of long stiff setae, bordering the outer and inner margins. The propus is about as large as the preceding joint and circumscribed along two borders by stiff setae and four ventral as well as two dorsal spines, the greater part of which are larger than the spines on the other joints. The dactylus is spiniform, only slightly stouter than the spines of the propus, and ends in a terminal claw. The exopodite is two-jointed, the shorter apical joint being tipped by six plumose spines.

The second and third peraeopoda are identical to each other in their structure. The basis is slender, elongate, sparingly fringed with short hairs on the dorsal border and with longer hairs on the ventral border, which ends in a bundle of a few setae. The ischium is short, carrying a few hairs at the ventro-distal angle. The merus is less than half as long as the basis, and armed with stiff setae disposed in dorsal and ventral rows and in subterminal transverse row of the outer face, besides carrying a dorsal and a ventral spines at the end of the joint. The carpus is subequal to the merus in size, bearing dorsal, ventral and outer subterminal transverse rows of setae. The propus is as long as the preceding joint, but somewhat narrower and flattened. In addition to the marginal rows of long stiff setae, the joint is furnished with another longitudinal row of three short setae on the outer surface. The dactylus is about as long as the propus, very slender, acuminating toward the sharp point and is curved ventrally like a sickle.

The fourth peraeopod differs from the preceding ones in structure, having somewhat broader basis, and the joints from propus to ischium are not flattened but cylindrical. The basis is only slightly shorter than the rest joints combined and is very sparingly setose, having three plumose setae gathering at the middle of the dorsal border and a few feeble hairs on the other border. The ischium is short, also sparingly setose. The merus and carpus are furnished with double row of short setae intermingled with a number of stouter spines on the ventral border, while entirely deprived of armature on the dorsal border. The double row of setae extends in the carpus as far as the dorsal angle of the terminal border both outside and inside. The propus is also armed with two ventral setae rows and a short plumose sensory hairs on the dorsal border near the base. Those rows are connected together dorsally to the base of dactylus so as to surround this; the constituent setae are apically pectinate for the greater part. Just outside these setae, the apical part of the joint is circumscribed by another series of short spinules closely standing on a horseshoe-shaped line. The dactylus arises from the ventral side of the propus a short distance behind the end, and is shorter than the corresponding joint of the preceding leg. It is styliform acuminating toward the tip, only slightly bent, and is furnished with two feeble dorsal hairs. The fifth perae-

Fig. 4. *Apseudes nhatrangensis* sp. nov., female. A, 2nd peraeopod (left), external view; B, 4th peraeopod (right), external view; C, same (left), showing ventral borders of merus to dactylus; D, 4th peraeopod, showing merus to dactylus (right), internal view; E, 5th peraeopod (left), external view; F, 6th peraeopod (left), posterior view; G, same, showing propus and datylus (left), anterior view; H, uropod (right), ventral view. A-C, E, F, H × 41, D, G × 83.

opod is substantially the same as the fourth save the minor differences in the disposition of setae and spines.

The sixth peraeopod is greatly different from the precedings in the armatures. The basis is thickly armed with long plumose spines making a row along dorsal and ventral margins. The ischium which is short as usual possesses a few simple setae at the ventro-distal angle. The merus and carpus bear plumose hairs fringing two opposite borders as well as the subterminal region of the outer face; the dorsal setae are much longer than the ventral ones. The propus has short stiff setae which are thickly set almost on the entire ventral border and, passing the inner side of the dactylus, extend as far as the dorsal end of the joint. At the base of this row there is a stouter spine and near the end a longer isolated seta is present. The subterminal region of the joint bears on the outside two feeble hairs irregularly fringed by finer secondary hairs. The dactylus is more powerful than in the preceding three peraeopoda, but similarly styliform and is attached to the propus subterminally.

Five pairs of pleopoda are uniform in structure, being composed of short, narrow, one-jointed protopodite and two elongate non-articulated rami. The protopodite is oblong ovate and fringed by long, rather flexible plumose hairs on both sides. The two rami are narrow elongate lamellae with rounded apices, the exopodite being a little shorter than the endopodite. Both are thickly circumscribed with long stiff marginal setae which are doubly edged with finer hairs.

Uropod is elongate, filiform, and about one and third times as long as the abdomen. The protopodite is about as long as the first three endopodite joints combined together and plentifully supplied with short hairs. The exopodite is one-fifth the length of the endopodite, and composed of ten subequal joints, each of which carries one or two setae at the end; the apical setae are longer than these. The endopodite consists of about 40 subequal joints and is armed with zero to two short hairs at each joint and with a larger number of longer hairs at every fourth, or fifth, or sixth joint.

Remarks: In the configuration of the body and the somites, the new species is resembling to *Apseudes tenuimanus gottliebi* Băcescu, but is entirely distinct from this form in the disposition of armatures on the cheliped and peraeopoda.

Apseudes nagae sp. nov.

(Figs. 5–8)

Occurrence: Station 297, between Hon-Lon and Hon-Mung —15′, muddy sand bottom, depth unknown, at 10: 30, on March 25, 1960. Two females. One of the females was dissected.

Female: Body is elongate, depressed, attenuating caudad, 9.1 mm long and 1.9 mm wide in the widest first peraeomere. Color in alcohol is white, lacking any pigmentation. The external cuticle is relatively thin, and thinner than in the

species described above.

The carapace is as long as the first two peraeomeres combined together, one sixth as long as the entire body and quadrangular in shape though somewhat narrowing forward. The anterior margin is arched in a V-shape and is accompanied by a well-developed triangular rostrum with a sharp median point which is produced farther into a short spine. On either side of this point the rostral margin is slightly excavated, and at each extreme lateral angle it forms a small round lobe which continues to the fore border of the carapace past a notch. The ocular lobes are located laterally to the rostrum, wider outward than inward, and neither with visual elements, nor with pigment. The antero-lateral angles of the carapace are not produced into a spine, but are furnished on the sternal surface with a triangular projection, which retreats from the general outline of the carapace and bears a few plumose hairs on the outer side. The lateral borders are nearly straight, only slightly inclining away from each other, and are notched some distance behind the fore end. The dorsal grooves are shallow but distinct. A sinuous transverse groove curved backward on the median combines the two lateral notches. A short groove arising from each antero-lateral angle of the carapace runs inward and backward so as to join the foregoing groove, and a short transverse one extends inward from the junction of those two, without meeting the corresponding member of the other side on the median. The groove combining lateral notches sends off from either side of its median sinus a pair of grooves which extend obliquely outward and as far back as the hind margin of the carapace. The cephalothoracic sternum bears at the hind end an anteriorly directed, blunt, median spine. Clypeus has a similarly disposed spine also.

The thorax occupies a little more than a half of the total length. All the peraeomeres are more or less tightly connected one with another, having their lateral parts slightly discontinuous. The first peraeomere is somewhat wider than the carapace and the succeeding ones decrease in length from before backward little by little. The first two somites are sticking fast to the carapace as well as to each other, and equal in their lengths. The following three which are of subequal length are a little longer than the preceding two, to which the last is equaling.

The first peraeomere is entire on the sides and has the lateral parts expanded backward into round lobes. It shows three pairs of longitudinal grooves on the dorsal surface in addition to the fore and hinder intersegmental grooves. The coxal plate is a narrowly triangular plate with a few plumose hairs and protrudes from the fore end of the segment further anteriorly on either side of the carapace. The second peraeomere resembles the first in contour as well as in dorsal grooves, but has no coxal plate.

In the succeeding peraeomeres the lateral parts are directed somewhat toward the rear and in increasing degree from before backward, and have a distinct notch behind the anterior angle, so that the margins are divided in all of them into a bluntly pointed, unguiform anterior process and a broader posterior lamella. The

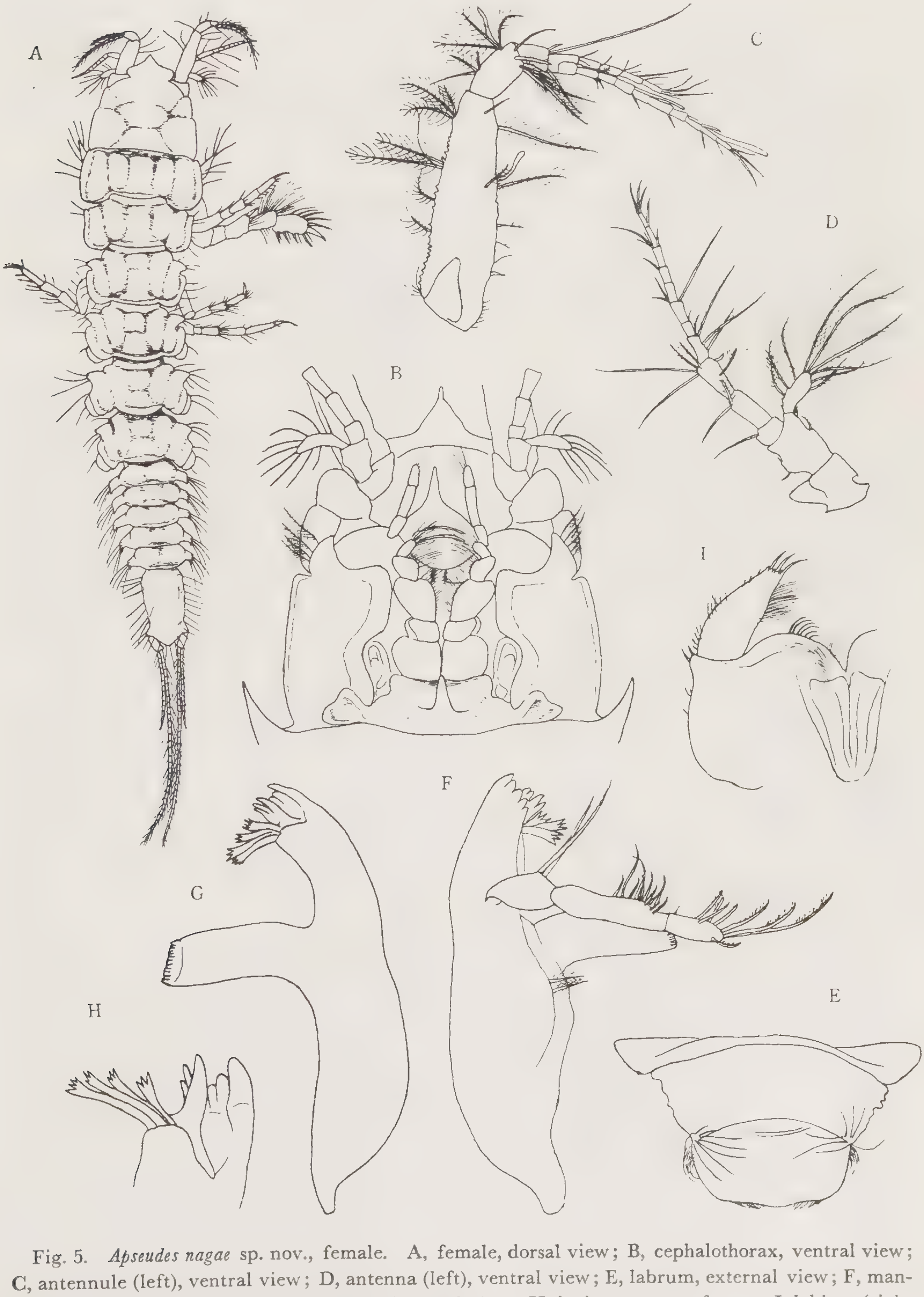


Fig. 5. *Apseudes nagae* sp. nov., female. A, female, dorsal view; B, cephalothorax, ventral view; C, antennule (left), ventral view; D, antenna (left), ventral view; E, labrum, external view; F, mandible (left), external view; G, same (left), internal view; H, incisor process of same; I, labium (right half), inner face. A × 13, B × 28, C, D × 48, E, I × 123, F, G × 93, H × 170.

dorsal grooves are more or less similar in those segments. The outermost of the three longitudinal pairs confines the base of the lateral lamella, and the members of the innermost pair are connected together by a short transverse central groove and join both in front and behind with the intersegmental grooves. The coxal plates are crescentic and distinct in the last three peraeomeres, projecting laterally from the marginal lamellae.

The sterna of all the peraeomeres are armed with a median spine. The spine is sharp, slightly inclining backward in the first peraeomere, whereas curved forward in the succeeding three, and thick and blunt in the last two. All the peraeomeres are furnished with numbers of plumose setae on the lateral margins inclusive of coxal plates and sparingly with similar ones on the intersegmental boundaries.

The abdomen is less than one third as long as the entire body and comprises five short subequal pleomeres and elongate pleotelson. The pleomeres are slightly narrower than the last peraeomere, insensibly decreasing in width from the first to the last, which is a little longer than the others. They are transversely linear and discontinuous in the lateral parts. The central part of the segments forms a pair of low round bulges which interpose between each other a slight median depression. The lateral parts are turned somewhat ventro-posteriorly, narrowed distally and truncated at the end, forming an obtuse anterior angle and an acuter posterior angle which, at times, is produced into a spiniform process. These parts are heavily fringed by rather long plumose setae chiefly at their truncated ends.

The pleotelson is narrow, elongate, slightly tapering caudad, about three quarters as long as five pleomeres combined together, half as wide as the first pleomere, and less than twice as long as its own width. It is serrated on the lateral margin, expanded at the posterior angles into triangular bulges to receive the uropoda, and has a semicircular caudal margin with a blunt median point. The pleotelson is circumscribed on all sides by long plumose setae and sparsely beset with short simple hairs on the dorsal face.

Antennule is biramous and composed of three-jointed protopodite, five-jointed shorter internal and ten-jointed longer external flagella. The first peduncular joint is elongate and stout, more than twice longer than the succeeding two joints combined together, and have the inner border more or less tuberculated. It is armed with a number of long plumose hairs on both outer and inner borders. The second joint is short and surrounded by plumose setae around the terminal border, besides having a few similar hairs on the inner border about the middle. The third joint is again shorter and narrower than the second, and has a few simple terminal setae, one of which is so long as to reach beyond the tip of the inner flagellum. The latter is provided with one or two short hairs on each joint, and tipped by a larger number of longer hairs; the first joint makes on the outside a rectangular excavation from which the external flagellum is issued. The external flagellum carries one or two hairs in every second joint in addition to the apical bundle of hairs; the

Fig. 6. *Apseudes nagae* sp. nov., female. A, body, from carapace to last peraeomere, right half, dorsal view; B, abdomen, dorsal view; C, thorax, lateral view; D, maxillula (right), external view; E, spines on the endites of same (right); F, maxilla (left), external view; G, spines on the 2nd basis endite of same (left), internal view; H, spines on coxal endite of same (left), internal view; I, 1st pleopod (left), anterior view. A–C × 19, D × 123, E × 170, F × 43, G, H × 340, I × 53.

fourth and eighth joints carry a long filamentous sensory hair.

Antenna is much shorter than the antennule, consisting of two-jointed protopodite, short one-jointed exopodite in the form of a squama and elongate eleven-jointed endopodite. The first joint of the protopodite is without setae, but with an inner triangular projection. The second joint is more or less uneven on the sides and has a few scattering short setae. The exopodite is subequal to the second endopodite joint, oblong ovate and encircled by a series of long plumose hairs. The first joint of the endopodite is broad, but short, with a single spine on the inner side. The second and third joints are far longer, carrying a simple and a plumose terminal setae on the second, while a larger number of terminal and middle setae on the third. The fourth joint which is shorter and narrower has four plumose setae along the outer border. Being of subequal lengths, the rest joints bear zero to four simple terminal spines, of which the inner one of the sixth joint is far longer than others.

Labrum consists of a broadly trapezoid base, which is uneven on the sides and ends in a pair of bundles of hairs, and a crescentic terminal lobe marginated by couple of series of short hairs.

Labium is bilobed due to the median incision, on either side of which it is fringed by inner series of short soft hairs and outer series of heavier hairs and has a submarginal hairy zone. The accessory lobe located at the extreme lateral angle of the basal lamella is narrowed distally, ending in three spines. It is thickly edged by long setae on the inside and scattered by shorter setae on the outside.

Mandible has molar and incisor processes elongated and columnar, the two making a right angle. The incisor process is somewhat curved and divided at the apex into five teeth which are accompanied just behind in the left mandible by a lacinia mobilis with four teeth. The accessory setae are four in number and expanded at the tip which is deeply serrated. The molar process is finely granulated on its grinding surface. The palp is three-jointed, the second joint being about twice as long as the other joints which are subequal to each other. The first joint has two long, simple, subterminal setae on the inner side, the second bears in the distal half a large number of much shorter hairs, and the third carries in the apical region several long and short ones, all of which are finely pectinate near the tip.

Maxillula possesses two slender endites and two-jointed, posteriorly directed epipodite. The precoxal endite bears at the apex eleven blunt spiniform teeth and two finer spines a little behind these. The endite of the basis is tipped by five stout plumose spines, all equal in structure. Both of the endites are heavily fringed by stiff hairs on both outer and inner borders. The palp is rod-like; the second joint is shorter than the first and furnished in the terminal region on the inner border with four long filamentous hairs. The terminal one of these is especially long, attaining to twice or thrice of the others and with double row of short fine hairs in its distal half. The other filaments are more or less broadened at the apical part where they are doubly edged with tiny hairs.

Maxilla is broadly lamellar. The coxal gnathobase is marginated by a series of long simple, stiff, closely standing setae which are intermingled with a few setae with terminal pectination. The gnathobase is elongated distally into a quadrate lobe with two sorts of setae or spines. The basal series of these is composed of five thick spines forked into a few branches; the basalmost spine shows a serration in its apical part. The terminal series is made from a number of simple setae, and there is a stout plumose spine behind these on the posterior surface. In addition to these armatures, the coxal surface is scattered by tiny hairs in the inner basal portion, by several short cirri on the outer border near the base, and bears rows of soft hairs at the inner proximal as well as at the outer distal angles. The first endite of the basis is closely beset with simple setae on the free margin, and the second endite is bordered by longer stouter, pectinate spines and by similar two located in the subterminal region of the outer margin.

Maxilliped has four-jointed palp and broadly expanded epipodite. The basis is broad, about as long as wide and expanded into a semicircular endite. The basis proper bears a short spine on the posterior face near the end and three small pointed prominences on the outer margin near the distal angle and the endite is cut into a larger number of similar processes on the same margin. The latter is armed with a row of simple setae and feeble hairs at the apex, with three retinacula on the outer edge of the median vertical surface, and with a row of plumose setae on the inner edge of this surface. The first joint of the palp is short, narrow and non-hairy except for a feeble spine at the outer distal angle. The second joint is longest and widest of all the joints, plentifully supplied on the inner border with two rows of short curved hairs as well as with three far longer submarginal plumose setae, and carries two stout spines at the outer distal angle. The third joint is shorter and narrower than the second, produced inward into a round lobe which is marginated by a row of shorter hairs and by another row of far longer hairs. The fourth joint is quadrate, terminating in long and short, simple or pectinate setae.

Cheliped is relatively slender and feeble, held parallel with the body and composed of five joints, the basalmost of which carries two-jointed rudiment of exopodite. The axis of this limb is bent twice, the geniculation intervening between basi-ischium and merus as well as between carpus and propus. The basi-ischium is bulged on the posterior side, but only slightly reentrant on the anterior side and possesses a stout spine directed distally on the former side besides a few short hairs near the base and at the distal angle. The merus is shorter and narrower than the preceding joint and scattered over the surface as well as on the ventral border with simple setae. The carpus is inserted to the distal half of the merus with which it is parallel. It is far longer than the merus attaining to one and half times the length of the latter and is scatteringly provided with long simple setae along the ventral border and over the outer surface extending as far as the dorsal border. The propus, which forms a swollen, but relatively narrow hand, is elongate

Fig. 7. *Apseudes nagae* sp. nov., female. A, maxilliped (left), external view; B, same (left), internal view; C, cheliped (left), external view; D, chela of same (left), external view; E, same, internal view; F, exopodite of same (left), external view; G, 1st peraeopod (left), external view; H, merus of same (left), internal view; I, exopodite of same (left), external view; J, 2nd peraeopod (left), external view; K, uropod (right), dorsal view. A, B × 93, C, G, H, J, K × 43, D, E × 85, F, I × 123.

distally into a recurved thumb which is about as long as the hand. On the inner margin the thumb is cut into a number of blunt, equal-sized, closely standing denticles, and on the outer face at the bases of the denticles it is furnished further with a sparse series of short hairs, which encircle the subapical region to extend along the ventral border of the thumb as far back as its base. The hand is supplied with a bundle of hairs on the dorsal face close to the base of dactylus and with a solitary one on this surface about the middle. A few setae are scattered on the inner face of the thumb also. The dactylus is slender, acuminated toward the sharp terminal claw and fits exactly to the thumb of the propus when closed, though the apices of the two cross each other. The dactylus has a few setae on the inner side behind the apex. The exopodite is composed of longer basal joint and shorter, narrower apical joint tipped by four plumose setae.

The first peraeopod is a powerful fossorial leg larger than the cheliped in the total length as well as in the breadth of joints which are more or less flattened. This leg is geniculated between merus and ischium and is provided with an exopodite rudiment at the base. The basis is long and broad, sinuous on the posterior border having a large triangular subbasal depression, though it is almost straight on the anterior border. It is furnished on the posterior border about the middle with a short plumose hair and at the distal angle of the same border with a stout spine and a few long simple setae. The ischium is short, and has a few setae at the postero-distal angle and inconspicuous ones at the opposite angle. The merus is again elongated, about two thirds as long as the basis, and broader distally than proximally. This joint is armed with two terminal spines, one at each of the outer and inner angles, and with long setae which are disposed in four groups; the first of these is the subterminal group of several setae present on the outer face near the dorsal border, the second is another subterminal group of two on the ventral border, the third is another group of two located behind the second, and the fourth comprising five hairs forms a transverse row on the inner face on the same level as the third group. The terminal border has two tiny hairs on the outer side at about the middle. The carpus is shorter than the merus and is plentifully supplied along the dorsal border with very long setae, which are associated at the end with a stout spine. Besides, it has three shorter setae interposing two stout spines on the ventral border and two very tiny hairs on the terminal border on the outer surface. The propus is narrower than the merus, and yet flattened. It is armed with four strong spines on the uneven ventral border as well as with a row of long setae mingled with a terminal and a subterminal spines on the dorsal border. The dactylus is stouter than the marginal spines on the propus, blunt at the tip, more or less tuberculated on the ventral border, and bears tiny subapical hairs. The exopodite is as in the preceding limb in structure, but with six terminal spines.

The second and third peraeopoda are similar in constitution to each other and have joints much narrower than in the first peraeopod. The basis is elongate, having the axis somewhat flexed in an S-form, and furnished along both dorsal and

Fig. 8. *Apseudes nagae* sp. nov., female. A, 4th peraeopod (left), external view; B, same (left), distal joints, internal view; C, tip of same (left), internal view; D, 5th peraeopod (right), external view; E, same, internal view; F, same, distal joints, internal view; G, same, merus and ischium, internal view; H, 6th peraeopod (left), external view; I, same, internal view; J, tip of same, external view. A, B, D, E, H, I × 43, C × 170, F, G, J × 85.

ventral borders with a number of long setae which are doubly fringed by sparse soft hairs. This joint terminates on the ventral side in several stiff simple setae. The ischium is short, and yet proportionally better developed than in the preceding

leg. It is armed with two plumose hairs on the dorsal side and with a few stiff simple setae at the ventro-lateral angle. The succeeding three joints are longer than the ischium and subequal among them. The dorso-lateral angle of the merus is crowded with several stiff setae and a spine, and the ventral border is fringed by a few setae and a feeble terminal spine. The carpus is rimmed along the dorsal border with long, closely standing setae and on the ventral border with a row of similar but sparser ones, and bears on the outer surface four feeble spines disposed in a subterminal transverse line. The propus is more or less resembling to the carpus in the arrangement of setae, but is lacking in the subterminal spine row. It bears three feeble spines, one on each side of the dactylus and the rest at about the middle of the dorsal margin. Just behind the latter on the inner surface, there is a short aesthetask ending in a tuft of short hairs. The dactylus is slender and sickle-shaped, ending in an acuminated ungulus.

The fourth peraeopod is somewhat dissimilar to the preceding two in the disposition of spines and setae. Plumose setae on the basis are three in number making a longitudinal line on the posterior surface, and simple setae at the ventro-distal angle are fewer in number. The ischium has a feeble spine and a seta at the ventro-distal angle and a single plumose seta on the dorsal side. In the succeeding three joints the ventral spines and setae roughly make a double row. The merus has two subterminal spines and a single dorso-terminal plumose seta. The carpus is armed with two spines at about the middle, with a single stout spine on the outer face, and encircled by a ring of spines intermingled with setae around the terminal border. The propus is crowded at the end with numbers of long and short setae, all of which are pectinate in the apical portion and surround two very long simple spines. The joint carries near the base on the dorsal side an aesthetask fringed with hairs.

The fifth peraeopod slightly differs again from the fourth in the armatures. The basis has double row of plumose hairs, and the carpus bears three similar hairs on the dorsal edge. The terminal ring of spines and setae on the latter joint is smaller in the number of constituents. The terminal setae of the propus are also less numerous, mingled with spines and replaced partly by a short ventral row of tiny spinules just behind the dactylus. The dactylus is slenderer and longer than in the preceding leg, ending in a sharp ungulus and carrying a few tiny hairs. In general, the spines on the fifth leg is stronger than those of the fourth.

The sixth peraeopod has entirely different armatures. The ischium is armless. The basis, merus and carpus are thickly fringed with long plumose hairs along both dorsal and ventral borders, the hairs extending even to the terminal border of the posterior surface of the merus. The carpus has an isolated subbasal spine on the same surface and another subterminal one on the ventral border. The propus bears a strong subbasal ventral spine and three, terminal and subterminal, dorsal spines. Connecting those spines there are a large number of short plumose spinules which are closely set on a line along the ventral border of the joint. In

addition to these, the joint is armed on the posterior surface about the middle with a spine, and near the dorsal border in the terminal half with a plumose seta, an aesthetask and a tiny spinule. The dactylus is as in the preceding limb.

Four pairs of oval rudiments of oostegites are present close to the bases of the first to fourth peraeopoda.

Five pairs of pleopoda are all similar in structure, consisting of oblong ovate, one-jointed protopodite and two narrow, lanceolate, one-jointed rami. The protopodite is furnished with plumose setae on both outer and inner borders. The exopodite is a little shorter than the endopodite and the both are heavily fringed by plumose setae which are graded in length proximo-distally.

The uropod is elongate filiform, about a quarter longer than the abdomen and composed of short, but broad, one-jointed protopodite, shorter, approximately 13-jointed exopodite, and longer, about 26-jointed endopodite which reaches twice the length of the exopodite. The protopodite bears plumose hairs around the terminal border and on the outer border. Both the rami are encircled by similar hairs at the end of every third, or fourth, or fifth joint besides carrying zero to two hairs in other joints. The apical setae are much longer than those.

Remarks: This species is nearly allied to the one described before in the general body status and in the major characteristics of the appendages. But they are entirely different in the minor details of the armatures of segments as well as of legs.

Apseudes gallardoi sp. nov.

(Figs. 9–12)

Occurrence: Station 72, depth 15 m, coarse brown sand bottom, at 8: 15, on January 19, 1960. One female. Station 262, depth 16 m, medium brown sand bottom, at 10: 35, on March 18, 1960. One female. Station 264, depth 9 m, coarse calcareous sand bottom, at 8: 45, on March 21, 1960. The specimen from station 262 was dissected.

Female: Body is excessively slender, attenuating from the first peraeomere little by little backward, and cylindrical rather than depressed. 4.9 mm × 0.85 mm. Color is whitish to very light brownish in preservative, without pigment. The external cuticle is rather thin.

The carapace has the length equaling to the width as well as to the combined length of the first two peraeomeres, and is somewhat narrowed toward the front. The fore margin is gracefully arched in the central region except for the possession of short spiniform rostrum, and is excavated on either side to receive the insertion of antennule. From the base of this excavation a longitudinal fissure directs backward for a short distance, so that the antero-lateral angle of the carapace is divided into an internal triangular lobe and a well round external lobe which continues to the sternal surface. The ocular lobes are coalesced with the

Fig. 9. *Apseudes gallardoi* sp. nov., female. A, female, dorsal view; B, abdomen, left half, dorsal view; C, cephalothorax, ventral view; D, antennule (right), ventral view; E, antenna (right), ventral view; F, labrum, external view; G, mandible (left), external view; H, incisor process of same (left), internal view; I, molar process of same (left), internal view; J, labium, right half, external view; K, uropod (left), dorsal view. A × 25, B, C × 43, D, E, J, K × 85, F × 170, G × 123, H, I × 340.

fore margin. The lateral borders of the carapace are uneven, having two slight notches, one at a short distance behind the anterior angle and the other at about the middle of the whole length; the antero-lateral spine is lacking. The dorsal surface is shallowly grooved in a complicated manner. Three pairs of short grooves arising from the carapace margin converge toward the centre, one pair taking origin in the inner angle of the triangular lobes of the fore margin and the rest in two pairs of lateral notches. The central region of the carapace is encircled by a horseshoe-shaped groove which receives the ends of the above-named pairs. Right and left halves of this groove are connected with each other by two transverse grooves both of which are interrupted on the mid-dorsal line. The posterior member of the transverse grooves extends farther laterally beyond the circular groove to reach another groove running near and parallel with the hind border of the carapace. The clypeus has a median spine similar to the rostrum, and the sternum in the region between the cheliped bases bears a sharper median spine directed forward.

The thorax is elongate, reaching three-fifths the body, and has the somites loosely connected except the intimate association of the first peraeomere with the carapace. All the peraeomeres are discontinuous on the sides owing to intervention of short narrow articulating part between every consecutive two. They decrease in width gradually from before backward, the last peraeomere being reduced to about two-thirds of the first. The first two and the last peraeomeres are of equal length and shorter than the third to fifth which are equal to one another. All the peraeomeres are nearly quadrangular in outline and have a pair of submarginal longitudinal surface groove as well as a short inconspicuous transverse groove traversing the center of somite except in the first peraeomere where this is absent.

The first peraeomere has the lateral parts entire on the margin and expanded slightly forward and backward. It carries a pair of triangular coxal plates which are acutely pointed forward and disposed vertically to the side of carapace, so that they are hardly visible in a dorsal aspect.

The second peraeomere is also entire on the margin and without coxal plates. The rest peraeomeres are divided on the lateral border into anterior and posterior parts by a distinct notch. The posterior part is little longer than the anterior in all of them and bears a narrow coxal plate, which, occupying the entire length of the posterior part in the third peraeomere, grows shorter successively toward the last and becomes to be displaced to the posterior corner of the segment in increasing degree.

All the peraeomeres are more or less setose along the lateral borders as well as on the surface. The sternum is unarmed in the first four peraeomeres, but is provided with a feeble median spine on the fifth, and with two spines, respectively directed forward and backward, on the sixth. The rudiments of oostegites are missing.

The abdomen is relatively long, more than a quarter as long as the body and

comprises five pleomeres and pleotelson. The pleomeres are diminishing in length and width from the front toward the rear though only slightly, and are uniform in configuration. The first pleomere is a little narrower than the last peraeomere. Each pleomere is twice as long as it is wide, with straight intersegmental border, and well round on either side, where it is produced into an acuminating, somewhat posteriorly curving, beak-like pleuron which is fringed by marginal as well as superficial setae.

The pleotelson is reduced in size, shorter than a third of the entire abdominal length, and narrower than long. It is roughly quadrangular in shape, having more or less uneven sides which bear anterior and posterior bulges, and is well round on the caudal margin except for a round median protuberance. The pleotelson is supplied with hairs around the margins, but deprived of these on the surface.

Antennule is about as long as the carapace and the first peraeomere combined together, and has three-jointed peduncle surmounted by four-jointed shorter inner and ten-jointed longer outer flagella. The first peduncular joint is very broad and long, occupying less than a half of the length of the antennule, and is serrated on both outer and inner borders besides carrying a stout spine on the latter border just behind the middle. The joint is armed further with long stiff setae, which make groups of two or three, one group lying close to the base of the inner spine, another in the subterminal region of the inner border, and again another exactly at the corresponding point on the opposite border. Besides these, the outer border is scattered also by short plumose hairs, and the inner border by a few short simple hairs. The second joint is one third as long as the first and half as wide. It is circumscribed around the terminal border by long and short, stiff setae, some of which belong to plumose ones, and is furnished with a few short hairs on the inner border about the middle. The third joint is again shorter and narrower, half as long as the second, and sparingly setose at the end. The inner flagellum reaches the fifth joint of the outer flagellum and is composed of four subequal joints, all of which end in two or three short hairs; the terminal hairs are large in number. The outer flagellum consists of ten joints unequal in length and carries a ring of short terminal setae at every second or third joint. The first joint bears plumose hairs and some of apical joints are supplied with long filamentous sensory setae.

Antenna is relatively small in size, about half as long as the antennule, and has a short, broad, one-jointed protopodite, surmounted by nine-jointed endopodite and issuing outward one-jointed exopodite. The protopodite bears two short setae on either border. The exopodite is narrow, short and fringed at the apex with six long simple setae. The first endopodite joint is very short, merely with a single stiff seta on the inside. The second joint is elongated, two and half times as long as the first and has two inner distal plumose hairs. The third joint is the longest of all, encircled about the middle of its length by a few plumose setae and furnished at the inner distal angle with couple of long stiff setae together with the same number of plumose ones. The rest joints are short, subequal in length, but gradual-

Fig. 10. *Apseudes gallardoi* sp. nov., female. A, maxillula (right), external view; B, precoxal endite of same, external view; C, basis endite of same, external view; D, maxilla (right), external view; E, spines on the endites of same, external view; F, inner spines on the coxa of same, external view; G, maxilliped (right), external view; H, same (right), internal view; I, epipodite of same (right); J, 1st pleopod (right), anterior view. A, D × 170, B, C, E, F × 340, G–I × 123, J × 85.

ly attenuating toward the tip, and are provided each with two or three simple setae, some of which are especially long. Apical tuft consists of several long stiff hairs.

Labrum is nearly trapezoid, being slightly insinuated on the sides and indistinctly bilobed on the terminal border. It has paired assemblages of hairs located on either lateral end of the transverse suture and feeble hairs along the free margin.

Labium is deeply incised on the median. Accessory lobe present at each lateral angle of the basal lamella is obovate, sparingly supplied with marginal setae on either border, and tipped by three sharp spines.

Mandible has the incisor and molar processes well-developed and the palp composed of three joints as usual. The incisor process is cut into four blunt teeth on the right mandible, whereas into five on the left member which is accompanied just behind with tridentate lacinia mobilis. Accessory setae are seven in number on the left, with bifurcate apices, except two which are simple. They are six on the right, simple or bifurcate or trifurcate. Grinding surface of the molar process is rasp-like and the marginal teeth are particularly deeply cut. The teeth are truncate at the apices in the anterior ones, acuminate in the middle ones, while finely pectinate in the posterior ones. The palp is tapering distad, the second joint being longer than the first and the last, which are subequal in length. The first joint is fringed with simple setae, the second with shorter pectinate ones, and the third with shorter subapical and longer apical hairs, all pectinate on their borders.

Maxillula is made of two slender endites and two-jointed backwardly directing palp. The precoxal endite has nine blunt terminal teeth, which are associated just behind with another tiny tooth, and a little farther back with couple of slender simple spines. The outer border of the endite is rimmed with a series of very stiff setae followed by feebler hairs, and the inner border is fringed by stiff but feeble hairs. The basis endite ends in four inner curved and an outer short straight spines, all plumose in structure, and has soft hairs on the inner border. The terminal joint of the palp is shorter than the basal and is armed on the inner border in the apical region with five filaments of unequal length having swollen apices circumscribed by short hairs. The terminal filament is unproportionately longer than others.

Maxilla is a more or less triangular lamella expanding distad as usual. The coxa is provided on the gnathal margin with long stiff setae scatteringly mingled with stouter, finely pectinate spines, and carries at the hind end of their row a single plumose spine. The endite prolongation of the coxa is fringed by two thick forked spines and three plumose spines besides by ordinary simple setae. The first endite of the basis is furnished with similar simple setae alone. These of the second endite are longer, pectinate, and associated externally as well as a little behind with two stout plumose spines. In addition to these armatures the maxilla is more or less ciliated on the outside as well as on the inside.

Maxilliped has four-jointed palp as usual. The basis is quadrate, slightly longer than wide and ciliated on the outer margin besides having a short plumose seta. The median vertical face of the basis endite carries four coupling hooks on the outer edge and a row of plumose setae on the inner edge. The endite is

spinulose at the apex and setose along the rest of the border. The first joint of the palp is furnished only with a short external spine and with two long terminal spines near the inner angle. The second joint is broadest and longest of all the joints and is provided with a very strong outer terminal spine. The third joint is shorter and narrower, and the fourth is again smaller. All of them are heavily armed with long and short, stiff setae along the inner border. The terminal expansion of the epipodite is oval, ending in a styliform process setose at the apex.

Cheliped is feeble, excessively slender in its figure and consists of five joints and two-jointed exopodite rudiment. It is geniculated between basi-ischium and merus dorsally and between carpus and propus ventrally. The basis is slightly recurved owing to the insensible concavity of the dorsal border, which is entirely armless, as well as to the strong convexity of the ventral border, on which it bears a short, but thick spine at about a distal third, two very long, simple and plumose, setae inserted in a row of very short hairs, and two long plumose subterminal setae. The merus is short, non-setose on the dorsal side, but bears a group of a few plumose setae respectively at the middle and at the end of the ventral border, and two simple setae on the outer face. The carpus is slender and about twice as long as the merus with which it is disposed in line by an oblique articulation. It is furnished with two sparse rows of long setae, simple or setose, on the ventral border, with a few short setae on the dorsal border and with a few terminal setae. The propus is slender, having the finger a little shorter than the hand. The finger is cut into a number of blunt, closely set denticles on the distal half of the inner border, and its blunt apex ends in a short ungulus. A regular row of short hairs encircles the outer face of the finger, extending from the base of the most proximal denticles toward the apex, then around this as far back as the base of the finger along the ventral border. In addition to this, groups of a few setae scatter on the propus here and there, above all, those encircling the base of the dactylus being conspicuous. The dactylus with relatively thick base tapers distally, ending in a sharp, slightly curved apex, behind which it bears three hairs. The exopodite rudiment is two-jointed; the apical joint is shorter than the basal and is fringed with four relatively long setae with double row of fine hairs.

The first peraeopod fossorial in structure has joints flattened and broader than in the succeeding ones, but is not so powerful and so well armed as in the ordinary case. The basis is half as broad as long, slightly recurved, sparsely setose on both the edges, and bears a few long hairs at the ventro-distal angle. The ischium is reduced and united with the basis. The merus is shorter and narrower than the basis and more or less triangular, being broader distally than proximally. It is armed with a thick blunt and a slender spines respectively at the ventral and dorsal angles of the terminal border. It carries, further, a number of long stiff setae making a transverse row on the outer surface at about the middle. The carpus is shorter than the merus to which it equals in width, and the propus is again elongated but narrowed. The carpus has two short, stout, blunt spines on

Fig. 11. *Apseudes gallardoi* sp. nov., female. A, carapace and thorax, left half, dorsal view; B, thorax, lateral view; C, cheliped (right), external view; D, same (right) showing chela, internal view; E, exopodite of same (right), external view; F, 1st peraeopod (right), external view; G, exopodite of same (right), external view. A, B × 43, C × 85, D, E, G × 170, F × 57.

the ventral border, one at about the middle and the other at the end, and another spine at the dorso-distal angle. The propus has four of similar spines along the ventral border and two on the dorsal border near the apex. All of the spines on

these two joints are associated at their bases with one or two setae, and their presence brings about the serration of the borders of the joints. Besides these, the merus is encircled around its dorso-distal angle by a setae row, and the propus is scattered by setae in the terminal half on the dorsal border. The dactylus is sickle-shaped, much stouter and longer than the spines on the preceding joints, bears a few short setae on the axis, and terminates in a strong ungulus. The exopodite is two-jointed; the terminal joint is a little longer than in the cheliped and has four terminal, one internal and one external setae, all doubly edged with fine hairs.

The second to fifth peraeopoda are more or less resembling to one another, differing in their armatures only slightly. All of them have short but distinct ischium and elongated basis. In the second peraeopod the latter joint bears a bundle of long stiff setae at the ventro-distal angle and is scattered by tiny hairs on both dorsal and ventral borders. The ischium has a similar terminal bundle of setae on the ventral side. The merus and the carpus are subequal in length and width, proportionately wider than the corresponding joints of the succeeding legs. The merus is fringed along the ventral border by a few setae followed by a feeble sub-terminal and a stronger terminal spines; the distal border has a few setae both at dorsal and ventral angles. The carpus has a stout short spine on the outer face near the ventral border at about the middle, a few long setae and a spine in the distal part of the same border, and another group of long setae as well as a spine at the dorso-distal angle. The propus is longer, but narrower than the carpus. The ventral border of the propus is armed at the proximal one third with a submarginal spine and two marginal setae, at about the middle with a marginal and a sub-marginal spines, at about the distal one third with marginal long hairs, and terminally with a spine together with a few setae. The dorsal border is marginated on the distal half with long setae, the proximalmost of which is plumose, and has two, terminal and subterminal, spines between which two setae are inserted. The dactylus is slender, elongate, about as long as the propus, styliform with a slight terminal curvature, and provided with a few hairs at about the middle of its length.

The third peraeopod is somewhat slenderer than the second which it resembles in the disposition of hairs on the first three joints. The carpus is also similar to the corresponding joint of the third peraeopod in the armatures, but the submarginal spines at about the middle of the joint is much feebler, the ventro-distal angle has two unequal spines besides the setae, and the dorso-distal angle possesses smaller number of setae and a stouter spine. The ventral spines of the propus are somewhat less strong than in the preceding leg and the submarginal spine is present only in one. The dorsal border has three spines instead of two. The dactylus is a little shorter than that of the second peraeopod.

The basis of the fourth peraeopod is relatively broader than in the foregoing two peraeopoda, and is armless except for a group of a few short setae on the dorsal border. The ischium is as in the third leg in constitution. The merus has two spines and four long setae on the ventral border and a feeble hair on the dorsal

Fig. 12. *Apseudes gallardoi* sp. nov., female. A, 2nd peraeopod (right), external view; B, 3rd peraeopod (right), external view; C, 4th peraeopod (right), external view; D, carpus and propus of same (right), internal view; E, 5th peraeopod (right), external view; F, 6th peraeopod (right), external view; G, end of propus of same (right), external view; H, ischium to carpus of same (right), internal view. A–C, E, F, H × 85, D × 170, G × 340.

border. The carpus has two spines disposed side by side on the ventral border at about the middle and six spines of unequal lengths which together with several long setae encircle the terminal border on all sides. The propus carries three setae on the ventral border, a number of long and short setae with pectinated edge at the dorso-distal angle, and a dorsal, sub-basal, plumose sensory process. The dactylus is again shorter than in the preceding leg.

The fifth peraeopod is more or less similar to the fourth, but different in that the basis has a few short plumose setae on the two opposite edges, in that the carpus bears two ventral spines arranged proximo-distally, in that the terminal setae and spines on the same joint are more or less concentrated toward the ventral side, and in that the propus has a stout ventral spine, a few short plumose hairs just behind the dactylus, and three unequal dorso-distal spines, the largest of which is only slightly shorter than the dactylus, as well as a few setae. The dactylus is a little longer than that of the fifth peraeopod. In other points the fourth and fifth legs are of the same structure.

The sixth peraeopod is dissimilar to the preceding walking legs in constitution. The basis is relatively narrow and scattered by several long flexible plumose hairs, ending in two stiff setae at the ventro-distal angle. The ischium is as that of the fifth peraeopod. The merus is fringed by a few simple setae along the ventral border and by five or six long plumose setae at the dorso-distal angle as well as just behind. The carpus has two unequal spines, arranged proximo-distally on the ventral border near the base, a stout ventral spine at the end which is associated with another feeble one of the inner face as well as with a small number of simple setae. It carries, further, four terminal or subterminal plumose setae in addition to another stout dorso-terminal spine. The propus bears a spine on the ventral border short distance away from the base and another similar one dorsally to the attachment of dactylus. Extending from the former spine to the dorso-terminal angle of the propus there is a regular series of sharp spinules closely set on a line which is curved dorsally at the apex of the joint. The dorsal border of the joint is fringed by a few short hairs.

The oostegites are absent.

Five pairs of pleopoda are uniform in size and structure; the two-jointed protopodite is surmounted by one-jointed exo- and endopodites. The basal joint of the protopodite is inconspicuous, constricted at the end to continue to the obovate apical joint which is about twice as long as wide and fringed outside with a small number of long plumose hairs. The exo- and endopodites are of subequal length, narrow, lanceolate, and heavily armed around their border with long plumose setae.

Uropod is filiform, longer than the abdomen and has one-jointed protopodite issuing shorter, four-jointed exopodite and far longer 16–20-jointed endopodite. The protopodite bears a few setae on the outer and terminal borders. The exopodite is composed of subequal joints and is hairy on the second joint as well as on the apical joint. The endopodite consists of more or less unequal joints and is setose

at every second to fourth joint, other intermediate joints being non-setose. The terminal tuft comprises a larger number of setae than those of other joints.

Remarks: The present species is readily distinguishable from the preceding two species for the first ground by its slender body, by the absence of any spines on the peraeomeres, and by its slender cheliped, not to mention the differences in the details of appendages.

This species together with the one to be described in the following might be assigned to *Apseudopsis* on account of the indistinctness of the ocular lobes from the carapace. This genus, however, was synonymized by LANG (1955) with *Apseudes* on the basis of his findings that in the species of *Apseudopsis* (*A. acutifrons*, *hastifrons* and *ostroumovi*, all belonging to one and the same species according to him) there are variations in the relation of the ocular lobes to the carapace ranging from their complete fusion to their complete separation.

Apseudes tenuicorporeus sp. nov.

(Figs. 13–16)

Occurrence: Station 146 I, depth 26 m, muddy sand bottom, at 14: 00, on February 23, 1960. One ovigerous female. Station 158 I, depth 14 m, mud bottom, at 13: 45, on February 24, 1960. One non-ovigerous female. Station 264 II, depth 9 m, coarse calcareous sand bottom, at 8: 50, on March 21, 1960. One non-ovigerous female. The female from Station 158 I was dissected and figured.

Female: Body is slender, elongate, filiform, cylindrical rather than depressed, widest in the carapace and the first peraeomere, the following segments being about of same width. 10.0 mm × 1.85 mm. External chitin is rather thin. Color is white to light brownish in preservative, without pigmentation.

The carapace is about as long as it is wide, one eighth as long as the body and almost quadrate in form. The anterior border is produced on the median into a semicircular rostral plate which has a short median spine and a marginal series of fine spinules on either side. Laterally to the plate, the border is excavated to form a pair of V-shaped sinuses into which the antennules are inserted. The sides of the sinus continue inward to the rostral plate through a slight incision and form outward the inner borders of the triangular antero-lateral processes. The lateral borders of the carapace are almost parallel to each other, though somewhat arched outward, and have a very slight incision at about the middle. The posterior border is somewhat undulated. The dorsal surface is traversed by a number of very shallow grooves. The most conspicuous is the horizontal groove connecting the lateral notches and dividing the carapace into anterior and posterior halves. The anterior half shows a H-shaped groove, the four limbs of H diverging away from each other and reaching the rostral base in front and the horizontal groove behind. Paired short curved grooves run transversely just behind the sinuses of the fore margin, sending each an oblique branch to the H-shaped groove. Along the

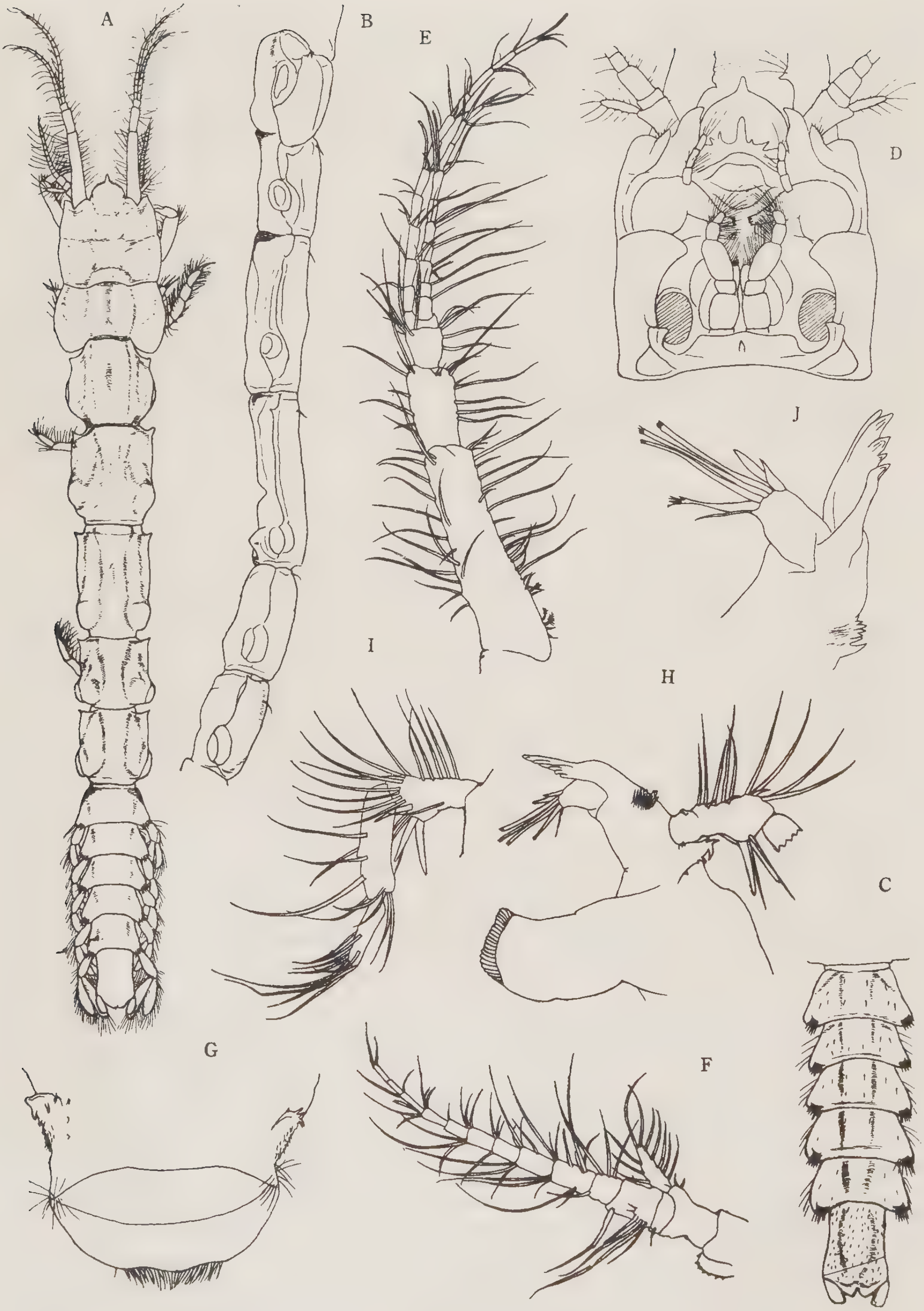


Fig. 13. *Apseudes tenuicorporeus* sp. nov., female. A, female dorsal view; B, thorax, lateral view; C, abdomen, dorsal view; D, cephalothorax, ventral view; E, antennule (left), ventral view; F, antenna (left), ventral view; G, labrum, external view; H, mandible (right), internal view; I, palp of same (right), external view; J, incisor process of same (right), internal view. A × 12.5, B, C × 16, D × 28, E, F × 43, G × 123, H, I × 85, J × 170.

posterior border of the carapace there is a shallow groove which is arched forward on the median and issues a pair of divergent branches forward to the horizontal groove. To these added are a pair of faint submarginal grooves which extend longitudinally from the fore margin of the carapace as far back as the hind margin. The sternal surface of the carapace bears two pairs of triangular anterior lamellae on either side of the clypeus, which is armed by a medio-anterior spine larger than the rostral spine as well as by two pairs of tiny lateral spinules. The sternal spine in the region between the bases of chelipeds is small and rudimentary. The carapace is non-setose and has the ocular lobe undifferentiated.

The thorax occupies more than a half of the entire body length. The first peraeomere is slightly wider than the carapace, whereas the succeeding ones are narrower than these, decreasing in width backward only slightly. The length of the first peraeomere measured on the midline reaches a little more than a half of the carapace. The somite is expanded in the lateral regions into broad lateral parts which extend back beyond the posterior articulation border. The lateral parts are widely rounded on the margin and obtuse at the posterior angle. In front, this segment is in intimate contact with the carapace, but narrow lateral crevices are left between this and the succeeding segments. The triangular, laterally pointing coxal plates are present at the fore end on both side. The surface grooves consist of a median longitudinal one, a submedian longitudinal pair and a submarginal pair inclining inward at the hind end.

The succeeding peraeomeres are more or less quadrate in shape and their narrow lateral parts are discontinuous. Of these, the fourth peraeomere being the longest, the lengths of the somites decrease in an order of the third, second, fifth and sixth; the last two are equal in length to each other reaching about two thirds of the longest peraeomere. The second peraeomere is as long as wide, widely round on the sides and is produced at each antero-lateral angle into an acutely pointed process. It has two pairs of longitudinal grooves on the dorsal surface, besides the mid-dorsal one. The third and fourth peraeomeres are longer than wide, whereas the last two have the length equal to the width. All of them have parallel sides, which are developed at the anterior end into a pair of acute spiniform processes and raised in a pair of low oval dorsal bulges near the posterior border. They have two pairs of faint longitudinal surface grooves in front of these bulges. The coxal plates are found only in the last two peraeomeres at the postero-lateral angles as narrow crescentic laminae. All the peraeomeres are lacking in the sternal spine and almost destitute of hairs except tiny scattering ones.

The abdomen is a quarter as long as the body, comprising five short pleomeres and pleotelson. The pleomeres are subequal in length and width to one another and are about as wide as the last peraeomere. Each of them is shorter than wide, trapezoid in shape, narrowing forward, and bluntly round at the caudo-lateral angles, where each bears a tuft of short stiff setae. The lateral border is fringed by longer feebler hairs, and the dorsal surface is scattered by shorter setae. The

Fig. 14. *Apseudes tenuicorporeus* sp. nov., female. A, labium, left half, internal view; B, maxillula (left), external view; C, basis endite of same (left), external view; D, precoxal endite of same (left), external view; E, maxilla (left), external view; F, endites of same (left), internal view; G, inner spines on the coxa of same (left), internal view; H, maxilliped (left), external view; I, same, internal view. A × 85, B, C × 123, C, D × 340, F, G × 170, H, I × 93.

pleotelson is twice as long as one pleomere, longer than wide and quadrate, having almost parallel sides and V-shaped caudal margin with a median notch. It is beset with tiny hairs on the dorsal surface.

Antennule is longer than the combined length of the carapace and the first peraeomere, and composed of three-jointed elongate peduncle and 12-jointed longer

inner and 10-jointed shorter outer flagella. The first peduncular joint occupying about two-thirds of the entire length of the antennule is about thrice as long as the second, which is twice as long as the third. The inner border of the first joint is more or less serrated. All the joints are thickly fringed with longer setae on the outer border and with shorter ones on the inner border. Besides, the second and third joints are encircled by numbers of setae around the terminal border. The inner flagellum is somewhat shorter than the peduncle. Its first joint is broad, issuing shorter outer flagellum from the outer terminal excavation. Other joints are narrower and of subequal length, carrying each at the distal end one to four setae. The joints of the outer flagellum are short in the basal portion, but more or less lengthened in the apical portion. Each of them bears a rather long seta besides shorter ones. Some of the apical joints of both the flagella are furnished with a filamentous sonsory hairs.

Antenna is shorter than the antennule reaching the second peduncular joint of the latter. It is composed of two-jointed peduncle, short narrow exopodite squama and twelve-jointed endopodite tapering toward the end. The first joint is broader than other joints and expanded internally into a semicircular lobe with a series of tiny spinules. The second joint is narrower than the first, but broadened distally to receive the exopodite, at the base of which it bears tiny hairs. The endopodite consists of twelve joints, the proximalmost of which is the shortest of all and has a tiny hair on the inside. The succeeding joints are subequal to one another and surrounded by a number of stiff setae chiefly on the terminal border. The second joint is crowded with setae on the inner border near the base. The exopodite is small, narrow and encircled around the margin with a regular series of hairs.

Labrum is widely round on the free margin, but more or less sinuous in its median region, the margin of which is densely hairy. It is also furnished with a tuft of hairs on each side of the base of the terminal lobe and with fine spinules further proximally.

Labium is bilobed and beset with tiny cilia on the inner face in a pair of small areas lateral to the median incision, and with somewhat larger spinules in narrow lateral areas. The accessory lobe is thickly fringed with stiff setae on both outer and inner borders, ending in three spines doubly edged with pectination.

Mandible has three-jointed palp. The first and second joints of the palp are subequal in length and width, and the third joint is narrower and shorter. The first joint has a series of long simple setae along the inner border as well as in the subterminal region which is reinforced by three stout spines. The setae with which the second joint is armed are similar to those of the first in disposition, but somewhat more sparsely distributed. The third joint is crowded with setae in the terminal and subterminal parts. The incisor process is cut into five acutely pointed denticles at the apex and associated just behind with a process surmounted by seven spines of unequal lengths; the longer spines are fimbriated at the apex, while the shorter ones are simply pointed. The process is thickly setose in a small area

of the outer side and has a spinulose protuberance just behind the base of the palp. The molar process has grinding surface granulated; the marginal denticles are tall, columnar and closely set.

Maxillula has two endites turned inward at the apex and the epipodite directed backward. The precoxal endite is surmounted at the end by five spines reinforced by a number of acuminating branches and doubly edged with finer hairs; the outer border of the endite is heavily setose. The endite of the basis is tipped by eleven spines simply attenuating distally, which are associated just behind with two slender but longer simple spines, and is fringed on the outer border with distal rows of long hairs as well as proximal series of short spinules. The epipodite is rod-like and composed of longer broader basal and shorter narrower terminal joints, the latter ending in five long filamentous appendages, which are somewhat swollen at the apices where they are doubly edged with tiny hairs.

Maxilla is a triangular lamella. The coxa constituting the greater part of this lamella is spinulose on the ventral face in a narrow submarginal longitudinal area and on the inner border in the region behind the rows of gnathal setae. The coxal gnathobase is heavily armed with long stiff marginal setae and beset with comb-like groups of tiny hairs on the inner surface in the submarginal region, behind which there is a single spine with forked apex. It is expanded distally into a quadrangular endite fringed by flexible setae with pectinated side and by several thick forked spines, some of which possess a fimbriated apex owing to the excessive furcation. The first endite of the basis is longer than the second endite and is marginated by curved pectinated setae. The second endite is armed with similarly pectinated setae which are far longer than those of the first, and groups of two spinules closely adjoining side by side make a row along the outer border.

Maxilliped is composed of very short, but broad coxa, quadrate basis and four-jointed palp. The basis has a fringe of soft hairs along the outer border and extends beyond the first joint of the palp as a triangular endite, which is marginated on the terminal border by a series of short blunt spines accompanied by a row of feeble setae and carries numbers of plumose hairs along the inner edge of the median surface as well as four coupling hooks on the outer edge of this surface. The first joint of the palp is short but broad and sparingly supplied with simple setae on the outer and distal borders. The second joint is the longest of all the palpal joints, and heavily armed on the inner border with long setae making two or three rows, and with a transverse row of similar setae on the distal half of the terminal border. The third joint is shorter, narrower and furnished merely with inner fringing setae. The fourth joint is again diminished in size and has numbers of terminal setae. The terminal expansion of epipodite is semicircular, somewhat irregular on the outer margin, and has an anterior crescentic accessory lobe fringed by hairs, group of hairs about the middle of the inner border, and a styliform posterior process surrounded by tiny hairs.

Cheliped is feeble, excessively slender, composed of joints far narrower than

Fig. 15. *Apseudes tenuicorporeus* sp. nov., female. A, cheliped (left), external view; B, chela of same (left), internal view; C, carpus of cheliped (left), ventral border; D, exopodite of same (left), external view; E, 1st peraeopod (left), external view; F, merus of same (left), external view; G, exopodite of same (left), external view; H, 2nd peraeopod (left), internal view. A, C, E, F × 43, B × 85, D × 170, G × 123, H × 48.

those of the next peraeopod, and has the ischium completely united with the basis without leaving any trace of union. It is bent twice and in opposite directions, the dorsal geniculation intervening between basi-ischium and merus, and the ventral one between carpus and propus. It bears a small rudiment of exopodite at the base of basi-ischium. The latter is somewhat convex on the ventral border, on which the joint carries two long setae about the middle and a tuft of short ones at the end in addition to a few scattering tiny ones. The dorsal border of this joint is also ciliated in the basal half and is furnished with a longer and a shorter spines in the terminal half. The merus is short, armed on the ventral border with double

row of long stiff setae as well as with two terminal and three subterminal short spines. The carpus is much elongated, in line with the merus, to which it is articulated by an oblique boundary. It is fringed along the ventral border with double row of stiff setae and close to the dorsal margin with terminal transverse row of similar ones as well as with a few dorsal subterminal ones. The propus is slender, but making together with the dactylus a relatively powerful chela which is longer than the basi-ischium. The terminal elongation of the propus, the thumb of the chela, is longer than the hand, slightly recurved and narrowed toward the tip which ends in a well-developed ungulus. Extending from the base to the tip, the inner border of the thumb bears a row of closely standing fine spinules which are accompanied by a sparse outer row of larger spinules, and the outer border has a sub-basal row of short hairs besides a fewer subterminal hairs. The hand is relatively narrow, and has dorsal and ventral groups of setae on the outer surface near the base and three solitary hairs, one of these locating in the dorso-subterminal region, another on the inner face at the base of the dactylus and again another just behind this. The dactylus is slender, acuminated and curved ventrally so as to come in contact with the thumb of the propus, the tip of which it exceeds for a short distance. It has a few solitary hairs on the dorsal border and two long hairs on the inner surface at about the middle, and is finely granulated in a subterminal area. The exopodite is small, composed of three joints, the middle one of which is the longest; the apical joint, which is short, bears four plumose setae, the external two of which interpose a tiny spinule.

All the peraeopoda have the well-differentiated ischium, and are geniculated between this and the merus. The first peraeopod, being fossorial in character, has the joints flattened and broader than those of any of the peraeopoda that follow. The basis which is broader than that of the cheliped bears a subterminal transverse row of several setae on the ventral side and a few short feeble hairs scattering along the ventral border. The ischium is short and furnished with ventral terminal hairs, which are fewer and shorter than in the preceding joint, as well as a few dorsal hair. The merus and carpus are broadly expanded, but the propus is narrower than these. All of the three joints are heavily marginated with very long stiff setae disposed in one or two rows on both dorsal and ventral borders. A sharp spine which is shorter but rather thicker than the setae is present on the merus at the end of the ventral row of setae. Two of similar spines are inserted also among the ventral setae in the carpus and four in the propus. The dactylus is feeble, only slightly larger than the ventral spines of the foregoing joints and has a bifurcate tip.

The succeeding peraeopoda which are walking legs are more or less similar to one another in their constitution, though they grow successively longer from the shortest second toward the last which is still somewhat shorter than the first. In all of them, the elongated basis has a few long setae at the ventro-distal angle, and is devoid of any other hairs except in the fifth peraeopod in which it is scattered

Fig. 16. *Apseudes tenuicorporeus* sp. nov., female. A, 2nd peraeopod (left), external view; B, 4th peraeopod (left), external view; C, tip of same (left), internal view; D, 5th peraeopod (left), external view; E, 6th peraeopod (left), external view; F, same, from carpus to dactylus (left), internal view; G, 1st pleopod, (right), posterior view; H, uropod (left), ventral view. A, B, D, E, H × 190, F × 85, H × 43.

by a few short hairs on the dorsal side. The ischium is distinct, relatively well developed, and carries a few setae at the ventro-distal angle. It has a tiny dorso-distal hair only in the last two peraeopoda. The merus is shorter than the carpus,

and the both are fringed along the ventral border by double row of setae. In the carpus the double row extends as far near as the dorsal angle of the terminal border on both the surfaces. The terminal end of the ventral border of the merus and the basal part of the same border of the carpus are more or less spinulose in the last two peraeopoda. In those as well as in the fourth peraeopoda, the propus has a row of spiniform processes along the ventral border in the basal part, and in all the peraeopoda it has double row of ventral setae which are more or less concentrated toward the apical part extending as far as the dorsal angle past the base of the dactylus. The propus has a short aesthetask doubly edged with hairs on the dorsal border near the base. The dactylus is bifurcate at the apex in the second and third peraeopoda, trifurcate besides having two short spiniform inner branches in the fourth, with sharply acuminating apex and three spiniform ventral branches in the fifth, and with a sharply pointed apex lacking in the side branch in the last.

Five pairs of pleopoda are well-developed and have two-jointed protopodite surmounted by one-jointed rami. Being issued from the ventral side of the pleomeres postero-laterally, they are visible from above in dorsal aspect. The protopodite is rather long, and fringed by long plumose setae on both outer and inner borders. The two rami are oblong ovate and broader than those of the species described above. The endopodite is somewhat longer than the exopodite and both of them are thickly encircled around their free border by a series of long plumose hairs.

The uropod is filiform, relatively short, about two thirds as long as the abdomen. The protopodite is short, one-jointed and furnished with outer and inner tufts of a few setae. The exopodite is only a little shorter than the endopodite. The former comprises 14 joints and the latter 17 joints. In both of them, every second or third joint is furnished with a number of setae at the end. The endopodite is scattered here and there by plumose aesthetasks, while the exopodite has simple filamentous ones. The apical bundle of hairs comprises only three or four in both the rami.

Remarks: This species may be recognized, for the first ground, by its slender body and its pleopoda which are exposed from the pleomeres in the dorsal aspect.

Apseudes nigrifrons sp. nov.

(Figs. 17–20)

Occurrence: Station 146 I, depth 26 m, muddy sand bottom, at 14: 00, on February 23, 1960. One specimen. Station 297, depth unknown, muddy sand bottom, between Hon-Lon and Hon-Mung –15′, at 10: 30, on March 25, 1960. One specimen. Both the specimens were dissected. The sex of the specimens was not decisively known, but they may probably represent the female.

Female: Body is depressed, stout, and relatively broad, somewhat tapering toward the rear. All the somites are scarcely setose. Color in preservative is light

greenish white; the carapace has reticular pattern of pigments in the fore region and narrower paired pigmented areas along the hinder border.

The carapace occupies one-fifth the length of the entire body and is the widest of all the somites, width surpassing its own length exclusive of the rostral spine. It is wider posteriorly than anteriorly. The fore margin is arched and produced in the middle into a crescentic rostral lobe which bears an elongate sharp spine directed forward. At either lateral end the fore margin forms a short triangular antero-lateral process which is a little concave on the inside, while convex on the outside. The rostrum and the antero-lateral processes interpose a pair of shallow depressions into which the bases of antennules are inserted. The lateral borders of the carapace show two very slight notches, one at the base of that process and the other just in front of the middle of the borders. Behind the latter notch the borders are swollen enclosing the branchial chamber within. The dorsal surface of the carapace is traversed by X-shaped grooves in its posterior region, fore limbs of X arising from the posterior notches of the side, the hind limbs reaching the hinder border on either side of the midline, and the junction of them making a short transverse groove. The posterior border is almost straight. The ocular lobe is indistinct from the carapace. The clypeus is armed with a sharp spine which is about as large as the rostral one, and the sternum in the region between the bases of chelipeds is prolonged into a long slender spine directed forward. The ventral parts of the branchiostegites lateral to the mouth parts are produced into two blunt forwardly directing processes.

The thorax is three fifths as long as the entire body and has the somites more or less discontinuous on the sides. The first peraeomere is as wide as the carapace and the widest of all the peraeomeres which are decreasing in width toward the rear little by little. The first, third and sixth peraeomeres are subequal in length and longer than the second, but shorter than the fourth and fifth which are again subequal to each other. All the peraeomeres are more or less quadrangular in shape. The coxal plates are distinct in the last four peraeomeres, but absent from the first two.

The first peraeomere is three times as wide as long and is in close contact with the carapace. It is widely round on the lateral margins, which extend a little beyond the central part of the posterior margin showing narrowly round posterior angles. The dorsal surface has three pairs of shallow longitudinal grooves, one being submedian, another submarginal, and the rest interposed between these. The second peraeomere has the lateral parts only slightly turned backward and evenly curved on the margin. It shows three pairs of surface grooves as in the first somite. The third to sixth peraeomeres are uneven on the lateral sides and are produced at the antero-lateral angles into a triangular, sharply pointed process which directs laterally. In the third peraeomere the margin is evenly curved behind this process, and the coxal plate is attached to the somite at about the middle. In the succeeding three peraeomeres the lateral margin is obliquely truncate at the hinder corner

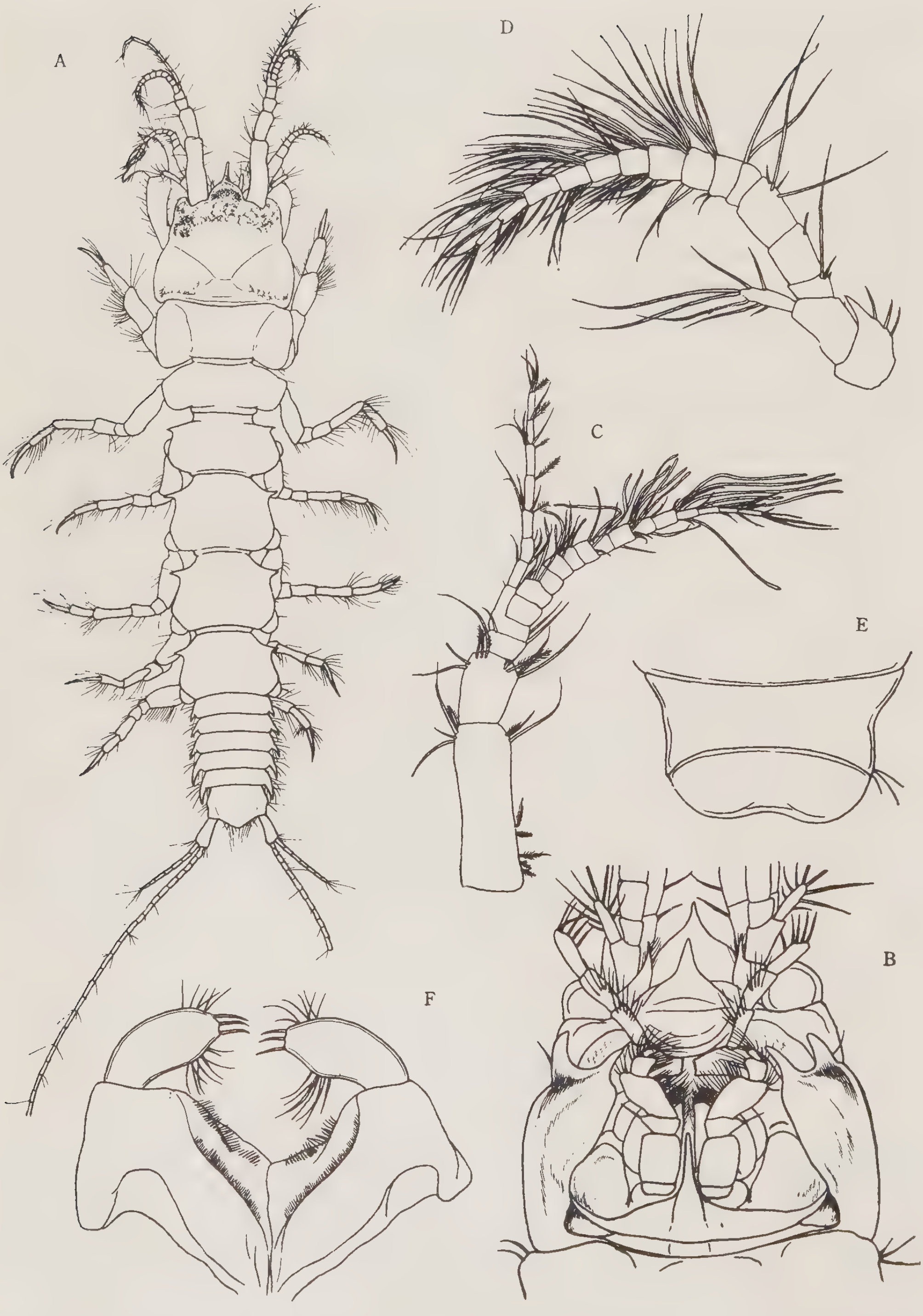


Fig. 17. *Apseudes nigrifrons* sp. nov., female. A, female, dorsal view; B, cephalothorax, ventral view; C, antennule (left), ventral view; D, antenna (right), ventral view; E, labrum, external view; F, labium, external view. A × 18.5, B × 28, C × 43, D–F × 100.

where they carry the coxal plate. These somites are lacking in the submarginal grooves.

The medio-sternal spine is well developed only in the second peraeomere, and in the form of an anteriorly directed sharp one, but rudimentary, or entirely absent in the others. The oostegites are absent. All the peraeomeres bear isolated setae along their anterior border on either side of the midline and at the extreme lateral ends as well as on the coxal plates in case where these are present.

The abdomen is about one fifth as long as the body, about two thirds as wide as its own length, and somewhat narrower than the last peraeomere. It comprises five subequal pleomeres and pleotelson. Each pleomere is short, but relatively wide, transversely linear, and has the pleura turned backward and downward, and acuminated toward the sharp apex. The pleura are better developed in the posterior segments than in the anterior, and beset with a few setae. The first pleomere bears a sharp, posteriorly directing medio-sternal spine.

The pleotelson is relatively short, wider than long, and half as long as the foregoing pleomeres combined together. It is pentagonal in shape, the two sides being uneven and somewhat divergent backward, and the caudal margin making a V-shape. Groups of two closely adjoining setae are issued from the lateral side, from the mid-dorsal surface in a pair and from the caudal margin on either side of the midline.

Antennule is well developed, longer than the carapace and the first peraeomere combined together, and consists of three-jointed peduncle and two multiarticulated flagella. The first joint of the peduncle is elongate and thick, about two and a half times as long as the second joint, and carries a few short plumose setae along the outer border near the base and a similar one mingled with some longer simple setae at the outer and inner terminal angles. The second joint is about as thick as the first and surrounded on the terminal border by simple and plumose hairs similar to those of the first joint. The third joint is very short, somewhat narrower than the second and furnished only with a few simple hairs. The inner flagellum is as long as the peduncle, filiform, comprising eight subequal joints. Its first joint, however, is broadened at the base to receive the same of the outer flagellum and prolonged at the inner angle into a joint-like process to continue to the inner flagellum; the base of this joint is as wide as the third peduncular joint. The inner flagellum is furnished with simple or plumose setae, especially heavily in the apical joints. The outer flagellum is composed of 14 joints, broader in the basal part, tapering toward the end, and plentifully supplied with long filamentous sensory hairs, which arise from the inner distal angle of every second joint, besides with shorter simple hairs.

Antenna is shorter than the antennule and consists of two-jointed peduncle, 13-jointed thick endopodite and one-jointed squamiform exopodite. The first peduncular joint is produced at the inner distal end into a sharp spiniform process, behind which the border has three short setae. The second joint is unarmed and obliquely

cut at the inner distal corner from which the exopodite arises. The latter is narrow, ending in long terminal and short subterminal setae. The endopodite is rather thick in its proximal portion, the first five or six joints having a uniform calibre, then tapering distally. The first joint is very short, the second and third are much longer, while the fourth is again shortened. All of these joints are rather scarce in setae, whereas all of the succeeding joints, which are subequal in length though successively diminishing in width, are heavily armed with long terminal setae both outside and inside.

Labrum is broad, more or less trapezoid, and somewhat bilobed owing to the presence of a shallow median depression on the free margin. It is hardly setose except for a few setae on the side.

Labium is distinctly bilobed, having the free margin deeply excavated and incised on the median. It is furnished with a marginal and a submarginal oblique rows of short cirri on either side of the incision. It bears at each outer distal angle an oblong ovate accessory lobe, which ends in three sharp spinules and has some subapical hairs on both outer and inner sides.

Mandible is stout, having three-jointed palp. The incisor process is cut at the apex into five blunt denticles on both right and left members. Lacinia mobilis present on the left mandible has also five denticles, two of which are rudimentary, and is more or less tuberculated on the inner surface. Accessory spines arise from the top of a columnar process and comprise three long and three short ones on the right mandible and five long and four short ones on the left; the longer spines are truncated or forked at their apices. Three joints of the palp are subequal in length, rod-like in shape, reaching beyond the carapace margin when extended; all of them are furnished on the inner border with multiple row of long and short, stiff setae, but the first joint is more sparingly setose than others.

Maxillula has the two endites relatively thick and the epipodite two-jointed and geniculated. The precoxal endite is surmounted at the top by eleven, relatively short, stumpy denticles which are associated just behind with two feeble pectinated spines. The endite is beset with hairs on the outer and inner margins as well as on the surface a short distance behind the tip. The endite of the basis has five terminal spines forked at the apex twice or thrice and ciliated on the sides. It is fringed with setae on the outer border. The apical joint of the palp bears just behind the apex five filamentous appendices, the basal two of which are shorter than the apical three, and terminates in a thicker, excessively long one. All of the filaments have an enlarged apex, where they are circumscribed by tiny spinules.

Fig. 18. *Apseudes nigrifrons* sp. nov., female. A, left half of body, dorsal view; B, thorax, lateral view; C, mandible (left), external view; D, same, incisor process (left), internal view; E, mandible (right), incisor process, internal view; F, maxillula (right), external view; G, basis endite of same (right), external view; H, precoxal endite of same (right), external view; I, maxilla (right), external view; J, spines on the 2nd basis endite of same (right), external view; K, spines on the coxal endite of same. A, B × 25, C × 85, D, E × 170, F × 100, G–I × 150, J, K × 425.

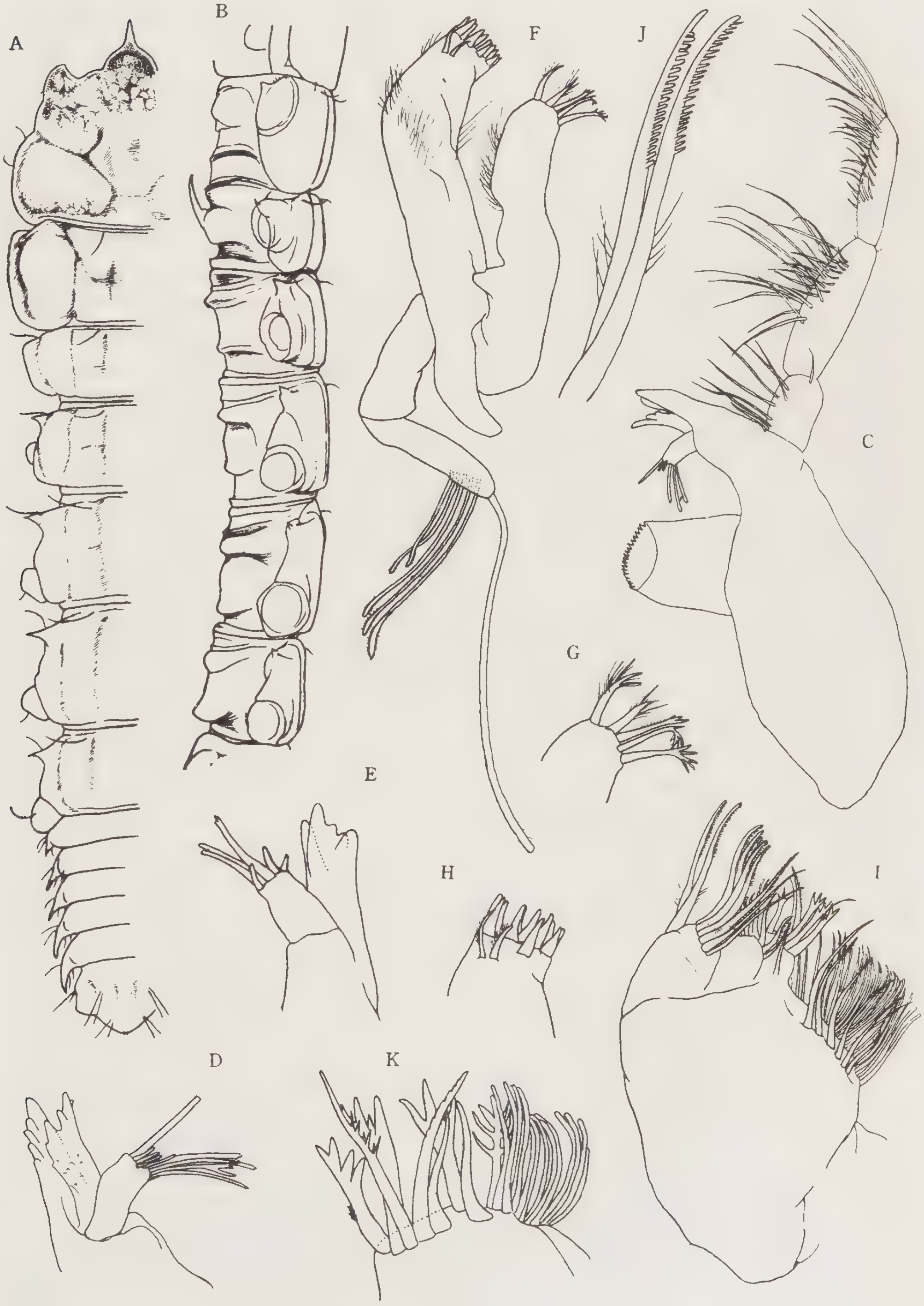


Fig. 18.

Maxilla is an oval lamella. The inner border of the coxa is densely fringed by long simple flexible hairs and bears a submarginal row comprising a fewer number of long setae doubly edged with pectination. The terminal endite prolongation of the coxa is armed proximally with several thick spines which are forked in varieties of forms, and with the distal bundle of ordinary simple setae. The first endite of the basis has shorter hairs, simple or pectinate, while the second endite bears much longer pectinate spines.

Maxilliped consists of short but broad coxa, basis with the endite, four-jointed palp and epipodite appendix. The basis is broad, quadrate in shape and provided with a semi-circular expansion of the endite. The latter has short simple spines intermingled with pectinate one along the terminal margin, a row of plumose spines on the inner edge of the median vertical surface and four retinacula on the outer edge of the same surface. The first joint of the palp is triangular, prolonged outward ending in a long simple seta, and bears a transverse row of long and short setae along the terminal border. The second joint is expanded, more or less rhomboid in shape, and carries a bundle of long setae at the outer distal angle, a few similarly long setae scattering over the outside face and a submarginal sparse row of similar ones along the inner border, which is fringed, as usual, with multiple row of short hairs. The third joint is shorter and narrower than the second and has inner marginal rows of short setae; several longer setae airse from the surface at the centre as well as near the outer distal angle. The fourth joint is again shorter and narrower, bearing the terminal group of long setae together with some external setae. Branchial appendage of epipodite is a cup-like, semicircular expansion which has a short narrow anterior lobe ciliated on the margin and ends in a styliform posterior process. The free margin of the epipodite is ciliated near the anterior accessory lobe for a short distance.

Cheliped is powerful, extending anteriorly far beyond the carapace to which it is held parallel. It consists of five joints and two-jointed exopodite rudiment. Geniculation intervenes between basi-ischium and merus and between carpus and propus, thus the axis of the leg describing an S-form. The basis is broad, a little less than a half as wide as long and slightly recurved dorsally, having somewhat concave dorsal and strongly convex ventral borders. It is narrowed at the base and furnished on the ventral border about the middle with a sharp, prominent spine directing distally and with a single terminal and a subterminal setae. The merus is short, narrowed at the base, expanded at the end, and the line of articulation to the carpus lies on the dorsal side of the joint and almost parallel with the ventral border, which makes an obtuse angle near the end. This joint is sparingly setose on the ventral side. The carpus is elongate, stout, almost of uniform width and only slightly narrower than the widest calibre of the basis, and has a sparse row of long setae along the ventral border. The chela is powerful. The propus, which has a triangular hand and a strong immovable finger of the chela, is only slightly shorter than the carpus and half as wide as it is long. The finger is broad at

the base attenuating toward the end, which terminates in a strong pointed ungulus. The inner border of the finger is armed with a sharp prominent triangular process, which is beset with tubercles, and with a row of minor denticles nine or ten in number, ranging from the point a little in front of that process to the ungulus. The hand is surrounded by long and short hairs around the base of dactylus interruptedly from the outside to the inside, and heavily armed with setae in the crevice between two fingers of the chela. The under surface of the hand and finger is also sparsely setose. In addition to these, each of the minor denticles of the finger is accompanied by a short hair, and a little downward on the outside there is a row of short, closely standing hairs. Another group of hairs is also present at the base of the terminal ungulus on the same side. The dactylus is well curved like a sickle, broad at the base and acuminated toward the pointed apex which surpasses the tip of the immovable finger. It bears a few long setae on the dorsal surface at about the middle. The exopodite is two-jointed, the basal joint being longer and attached to the basis by a short narrow peduncle. The apical joint carries three long and one short, plumose setse.

The first peraeopod is fossorial in function, having joints broadened and flattened, and bears two-jointed exopodite rudiment. The basis is elongate and armed at the ventro-distal angle with a strong spine which is followed by a short longitudinal row of several long stiff setae. The ventral border is also scattered by a few tiny hairs. The ischium is distinct but short, and has several terminal setae on the ventral side. The merus is triangular, furnished with two stout spines, one at each terminal end of the dorsal and ventral borders, the dorsal one being far longer than the other. Besides with scattering setae, the joint is provided with four oblique rows of stiff setae, these being disposed on both surfaces at about the middle, on the inner surface near the base of the dorsal spine and on the same surface close to the ventral spine. The propus resembles the merus in shape, but has an extra spine on the ventral border about the middle in addition to the ones present on the latter. Long setae with which the joint is armed make three rows, one of these running along the ventral border, another on the outer surface along the terminal border and the rest extending from the dorso-distal spine obliquely toward the centre of the outer surface. The propus is somewhat narrower than the preceding joint, and is armed on the ventral border with five spines inserted into the marginal row of long setae and on the dorsal border with two terminal spines besides with marginal setae. The dactylus is spiniform resembling the spines on the propus, but far stouter. The exopodite is as that of the cheliped, but tipped by five, long and short, plumose apical setae.

The succeeding peraeopoda are walking legs and have joints much narrower than those of the first. Of them, the fourth peraeopod is the shortest, others growing longer forward and backward. The second and third peraeopoda are similar to each other in their constitution. The basis is narrow, but elongate, and armed only at the ventro-distal angle with a few long setae. The ischium is in line with

Fig. 19. *Apseudes nigrifrons* sp. nov., female. A, maxilliped (left), external view; B, same (right), internal view; C, epipodite of same (left), external view; D, cheliped (right), external view; E, chela of same (right), internal view; F, chela of same (right), external view; G, exopodite of cheliped (right), external view; H, 1st pleopod (left), anterior view; I, uropod (left), dorsal view. A–F × 85, G × 170, H, I × 43.

the basis, short, and has a few terminal setae on the ventral border. The merus is longer and flexed dorsally in relation to the ischium. It bears a feeble spine at the ventro-distal angle, another shorter one a short distance dorsally, a marginal row of setae along the ventral border and a few setae scattering over the outer surface. The carpus is longer than the merus, carrying three ventral and three dorsal spines disposed on a line extending from the dorsal angle obliquely downward for a short distance. As for the setae of this joint, these are arranged in three lines, one on the ventral border, another on the submarginal region along the dorsal border, and another along the row of dorsal spines. The propus is expanded dorsally in an oval lobe at the end, the dactylus arising from its ventral corner. It has three spines inserted among the setae fringing the ventral border, a single spine just dorsally to the dactylus, and rather long setae on the dorso-terminal lobe. The dactylus is slender, longer than the propus and curved like a sickle with the acuminating end.

The fourth and fifth peraeopoda resemble the preceding two except for some minor differences in the disposition of armatures. The basis, ischium and merus of the fourth peraeopod are the same as the corresponding joints of the second and third, but the merus has merely a single spine at the ventro-distal angle. Two rows of spines and setae on the carpus draw nearer than in the preceding legs, one of the row running along the ventral edge and the other on the submarginal line and extending as far as the dorso-distal angle of the joint. The former row comprises three spines, while the latter only one. The propus has two feeble spines interposed among the ventral setae and two dorso-distal spines together with some hairs. The ungulus is feebler than in the foregoing limbs.

The fifth peraeopod has the basis more or less wider than in the fourth. The basis is armed along the dorsal border near the end with three short setae, near the base with a short plumose seta, at the ventro-distal angle with a solitary hair. The ischium is as in the preceding peraeopod. The merus is furnished with a single ventral row of feeble spines and setae near the end, and with a pair at the dorso-distal angle. The carpus is armed on the distal half of the ventral border with double row of spines and setae, which are not much different in thickness from each other. The outer row comprises three longer spines and the inner row the same number of shorter spines. It has a short spine at the dorso-distal angle also. The propus has ventral rows of spines and setae also, the inner and outer rows being continuous with each other behind the dactylus. It carries a plumose aesthetask on the dorsal side near the base. The dactylus is longer than that of the fourth peraeopod.

The sixth peraeopod is somewhat different from the preceding leg, for the first ground, in the possession of long plumose setae arranged along the entire dorsal border of the basis and a few simple setae linearly disposed in the distal part of the ventral border of this joint. Dorsal plumose spine is present on the merus in one, on the carpus in two, and on the propus in one which is short. The ischium is

Fig. 20. *Apseudes nigrifrons* sp. nov., female. A, 1st peraeopod (left), external view; B, merus of same (left), internal view; C, exopodite of same (left), external view; D, 2nd peraeopod (left), external view; E, 4th peraeopod (left), external view; F, fifth peraeopod (right), external view; G, same, internal view; H, 6th peraeopod (left), external view; I, tip of same (left), internal view; J, tip of same (left), external view; K, carpus of same (left), internal view. A, B, D–F, H × 43, C × 70, G, I–K × 85.

unarmed. The merus has a few ventral setae and a single spine at the ventro-distal angle. The carpus possesees two rows of spines and setae in the distal half of the ventral border, the outer row comprising four longer spines and the inner row only a single terminal one. The dorso-distal angle of the joint bears a small number of hairs. The propus is slender, armed with three long spines dorsally to the dactylus and with one ventrally to this, in addition to having some long setae. On the terminal half of the outer surface there is a longitudinal line on which tiny spinules are regularly and closely arranged. The dactylus is longer than the propus, curving and acuminating toward the sharp end.

The pleopoda are present in five pairs. They are composed of narrow elongate protopodite, which is edged on either side by long plumose setae, and two narrow, one-jointed rami which are circumscribed with similar, much longer marginal setae. The exopodite is shorter than the endopodite.

The uropod is filiform and longer than the combined length of the carapace and the first four peraeomeres. The protopodite is about as long as the pleotelson, and the endopodite is five and a half times as long as the exopodite. The protopodite bears a few terminal setae both outside and inside. The exopodite is slenderer than the endopodite and composed of nine subequal joints, of which the fifth bears two setae and the last ends in the apical group of setae. The endopodite comprises 27 joints, the basal joints being shorter than the apical ones. In general, every second joint is sparsely setose, the setae being longer near the apex of the endopodite than near the base, and the terminal joint ends in a tuft of setae.

***Pagurapseudopsis* gen. nov.**

Diagnosis: Carapace, six peraeomeres, five pleomeres and pleotelson distinct. Antennule with three-jointed peduncle and two flagella. Antenna simple, with five-jointed peduncle surmounted by single flagellum, and without accessory squama. Mandible with three-jointed palp. Maxillula with two-jointed epipodite. Maxilliped with four-jointed palp and branchial epipodite. Cheliped and first peraeopod with rudiment of exopodite. First peraeopod never fossorial, but ambulatory in character, being more or less similar to the succeeding peraeopoda in structure. Pleopoda five pairs, very slender, and composed of elongate styliform protopodite and two narrow rami. Uropod biramous, filiform.

Type-species: *Pagurapseudopsis gracilipes* sp. nov.

Barnard (1935) described from the sea of Cochin *Apseudes gymnophobia* Barnard which shares some important characters with the type species of the new genus to be described below. The characters common to the two consist chiefly in the simple second antennae, similarity of the first peraeopoda with the succeeding pairs and possession of five pairs of narrow, aciculate, biramous pleopoda. Although he recognized the importance of these characteristics, he hesitated to construct a new genus to accomodate his species. In my opinion, however, these may be considered enough

to warrant the establishment of a new genus.

Pagurapseudes Whitelegge and *Dalapseudes* Boone, both of which are similar to the new genus in the first two of those characters enumerated above, are entirely different in the possession of only three pairs of pleopoda. *Synapseudes* Miller allied to the new genus in the uniramous antennae differs in having only two pleomeres besides pleotelson.

Pagurapseudopsis gracilipes **sp. nov.**

(Figs. 21–23)

Occurrence: Station 8, depth 8 m, mud bottom, at 8: 50, January 7, 1960. One female. Station 102, depth 11 m, mud bottom, at 10: 00, February 5, 1960. One female. Station 106 I, depth 14 m, mud bottom, at 8: 30, February 10, 1960. One female. The female from Station 8 was dissected.

Female: Body is slender, depressed, with the carapace and the first two peraeomeres wider than the rest somites of thorax and abdomen, which are of subequal width. 6.7 mm × 1.2 mm. Color is brownish in alcohol, darkest in the carapace and the first peraeomere, becoming paler toward the rear. No pigmentation.

The carapace is nearly quadrate, but somewhat broader posteriorly than anteriorly, longer than wide by a quarter, and occupies about one fifth of the total length. The fore margin is arched forward and produced on the median into a short but broad rostrum, which is notched on the mid-dorsal line and angular on the sides. The antero-lateral spines are rudimentary, short and blunt. On either side of the rostrum, the fore margin of the carapace forms a shallow quadrate sinus into which an ocular lobe is inserted. The ocular lobe is triangular in shape pointing at the antero-lateral angle, lacking in both the visual elements and the pigments, but having tiny hairs on the ventral surface. The sides of the carapace are almost entire except for having a slight notch some distance behind the fore end, and are well round at the posterior angle to continue to the nearly straight posterior border. The central dorsal area is surrounded by triangularly disposed grooves, each angle of the triangle radiating couple of grooves outward; these grooves reach, respectively, to the inner angles of the antero-lateral spines, to the lateral notches, and to the lateral ends of the line of articulation with the first peraeomere. The clypeus bears conical, anteriorly directed, median spine, and the sternum just behind the maxilliped is raised in an anteriorly narrowing, medio-ventral ridge. The carapace is almost destitute of hairs on all sides.

The thorax is a little longer than the half of the entire length. Six peraeomeres are discontinuous on the sides, any two of the consecutive peraeomeres being connected together by a short, narrowed, neck-like anterior prolongation of the posterior member. The first peraeomere is also separated from the carapace, narrower than this, but wider than any of the succeeding peraeomeres, which are subequal to one another in width. The second, fourth and last two peraeomeres are about of

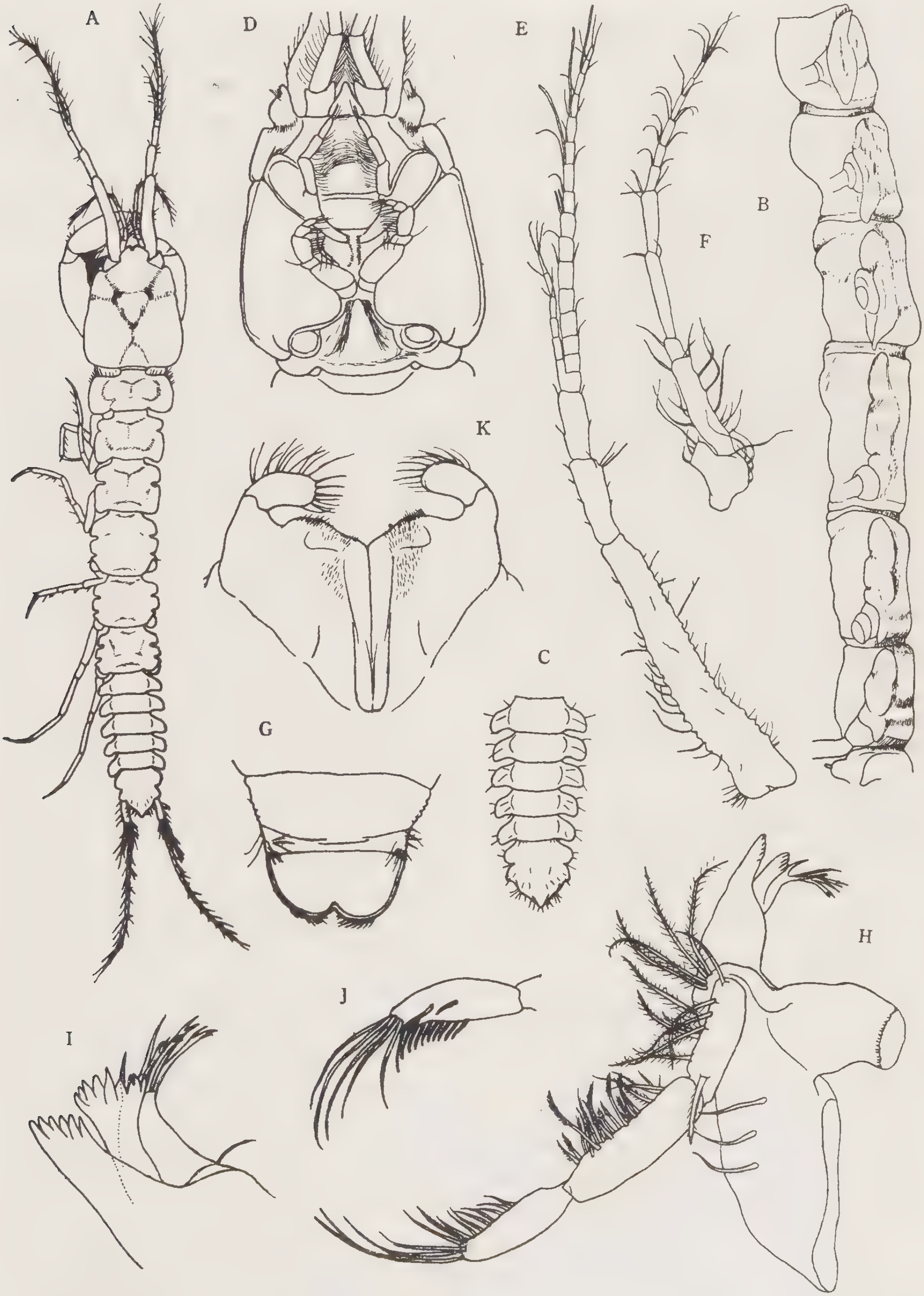


Fig. 21. *Pagurapseudopsis gracilipes* gen. et sp. nov., female. A, female, dorsal view; B, thorax, lateral view; C, abdomen, dorsal view; D, cephalothorax, ventral view; E, antennule (right), dorsal view; F, antenna (right), dorsal view; G, labrum, external view; H, mandible (left) internal view; I, incisor process of same (left), internal view; J, tip of mandibular palp (left), internal view; K, labium, external view. A × 13, B–D × 18, E, F × 41, G, H, J, K × 85, I × 170.

equal length and longer than the first, but shorter than the fourth.

The first peraeomere is broadly quadrangular, twice as wide as long, and has two sides entire and widely rounded. It is ciliated on the fore border on either side of the median articulation part, and has a shallow, Y-shaped, medio-dorsal surface groove and paired lateral grooves disposed like brackets. The second and third peraeomeres are quadrangular, wider than long, and round at both anterior and posterior angles of the lateral parts which have a notch behind the anterior end. The dorsal grooves on them consist of a T-shaped median and a broadly U-shaped ones located behind. The succeeding three peraeomeres are squarish, also well round at four corners, but are provided with additional pair of lateral incisions, the lateral parts thus being divided into three lobes. They have each a crescentic coxal plate at the posterior angle on either side. The surface grooves are more or less inconspicuous. The peraeomeres are carinated along the mid-ventral line, but the sternal spine is not developed in any of them. The lateral margins are sparsely setose in all of them. The oostegites are absent.

The abdomen is about a quarter as long as the entire body, comprises five pleomeres and pleotelson, and narrows from the first pleomere, which is as wide as the last peraeomere, toward the rear only slightly. The pleomeres are subequal in length and similar in size. Each of them is transversely linear, ending laterally in short, narrowed pleura. These are bordered from the central part of the somite by an indistinct fissure, somewhat turned backward at the rounded apex, and sparingly setose on the margin as well as on the surface.

The pleotelson is about half as long as the preceding pleomeres combined together and about as long as wide, narrowing backward. It bears at its anterior one-third on both sides paired incisions, in front of which the sides form a rounded lobe, and behind which these converge toward each other and are more or less undulated past the low angular projection. At the caudal end, it has a small triangular medio-dorsal bulge and a pair of low bulges just in front. The pleotelson is ciliated on the surface as well as on the margin, and more densely near the end than in the fore region.

Antennule is very long, as long as the length from the fore end of the carapace to the middle of the third peraeomere, and composed of three-jointed peduncle and multiarticulated flagella. The peduncle is longer than the outer flagellum which is two and a half times as long as the inner flagellum. The first peduncular joint is strongly elongate, twice as long as the second and third joints combined together, and serrated on both the outer and inner borders which are provided each with a row of short hairs. The second joint is far shorter and narrower than the first, and yet longer than the third; both the joints are setose on the two sides besides carrying outer terminal tuft of setae on the second. The inner flagellum is short, filiform and six-jointed. The first joint is broad at the base, but is produced into a short narrow rod at the inner distal angle so as to continue to the filiform succeeding joints, and is surmounted by the outer flagellum at the outer distal angle. The

apical three joints of the inner flagellum bear a few setae at the end. The outer flagellum is composed of joints broader than those of the inner. It comprises 15 joints of subequal length, but gradually narrowing distally. It is sparingly setose except in some of the basal joints and furnished with a long filamentous sensory hair in some of the apical joints.

Antenna is shorter than the antennule, a little longer than a half of the latter, and composed of elongated five-jointed peduncle and shorter filiform flagellum. It is lacking in the exopodite. The peduncle reaches the first joint of the same of the antennule. The first peduncular joint of the antenna is short but broader than the succeeding joints, and produced at the inner distal angle into a quadrate lobe. The second joint is longest of all the joints and is furnished, together with the first joint, with a row of long soft hairs both outside and inside. The third joint is short, whereas the next two joints are again longer, but narrower. All of these are armed with a few short terminal setae alone. The flagellum is as long as the last two peduncular joints combined, tapering toward the end and consisting of six subequal joints with terminal hairs.

Labrum is trapezoid and bilobed by the development of a shallow median notch, on either side of which the well round margin is ciliated. Two sides are more or less crenated near the base, and bear some short hairs at the junction of the basal and terminal lamellae.

Labium is deeply incised and folded on the midline. The two lamellae are thickly ciliated on the marginal and small submedian areas, and are surmounted at the lateral angle by a crescentic accessory lobe which is encircled by long stiff setae on the outside as well as at the tip.

Mandible has the incisor and molar processes, which make a right angle, and is provided with a rather long three-jointed palp. The incisor process is deeply cut into six relatively sharp denticles, and bears just inside of these a columnar process surmounted by six or seven spines which are for the greater part forked at the apices. Lacinia mobilis inserted between the biting edge and the accessory setae in the left mandible is divided into nine acuminate teeth at its enlarged apex. The molar process has the grinding surface, more or less oval in shape and finely granulated. The mandible carries three very long setae on the anterior edge behind the base of the palp and several long plumose setae just outside of this. The palp consists of three subequal rod-like joints, of which the basalmost is fringed on the inner margin by long plumose spines, the middle is more thickly covered by shorter pectinate setae besides by a few basal plumose ones, and the terminal is furnished with a row of simple setae, some terminal ones of these attaining much longer than others.

Maxillula is small and feeble in comparison with the mandible. The precoxal endite flexed inward near the apex ends in eleven blunt spines, some of which are doubly edged with fine pectination, and accompanies just behind a short spine and a short distance farther behind another long spine with a sharp tip and some sharp

Fig. 22.

side branches. The terminal region of this endite is beset with setae on the outer border and on the surface. The basis endite has a round apex densely covered with setae, amidst of which it bears four curved setiferous spines and a feebler simple spine located laterally to them. The epipodite is two-jointed, with joints rather stout. The second joint is longer than the first and possesses in the terminal region on the inside six long filaments arranged in a row and graded in length, the terminal one reaching four times the length of the basalmost. The filaments are thickly covered by tiny hairs in their terminal halves along two opposite sides.

Maxilla is a narrow elongate lamella. The coxa is fringed along the inner border by a regular row of long, rather flexible plumose setae and a few similar ones falling out of this row. The terminal endite of the coxa has several thick stout spines with forked apex, one of these being branched like a tree, in addition to the ordinary simple or plumose setae. The first endite of the basis is marginated by ordinary setae, some of which are ciliated on all sides, and is thickly setose in the narrow inner terminal area. The second endite bears several long stiff pectinated spines.

Maxilliped is slenderer than usual, but has an ordinary four-jointed palp. The basis is relatively short and narrow, quadrate in shape, and bears three long plumose setae arranged transversely near the terminal border. The endite expansion of the basis is marginated along the outer and terminal borders by fine hairs besides by the row of short stout spines on the latter. The median vertical face of the endite is edged by a row of short plumose setae on the inner border, and bears two coupling hooks on the outer border. The first joint of the palp has a single plumose seta merely on the outer side. The second joint is broad and elongated, larger than the coxa in size, thickly fringed by relatively short stiff setae on the inner border, on which a single plumose seta is inserted, and is furnished at the outer distal angle with a single simple seta. The third joint is narrower and much shorter than the second, wider distally than proximally, and is armed with several setae longer than those of other joints. The fourth joint is oblong ovate, carrying long stiff setae arranged along the terminal border. The epipodite is developed into a large cup-like expansion, which is thickly fringed on the margin with soft hairs and is elongated at the hind end into a filiform process with blunt hairy tip.

Cheliped is very powerful, extending forward far beyond the carapace when extended. It consists of five joints far broader than those of the succeeding peraeopoda and carries an exopodite rudiment. It is bent ventrally only once, the

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Fig. 22. *Pagurapseudopsis gracilipes* gen. et sp. nov., female. A, carapace and thorax, dorsal view; B, maxillula (right), external view; C, precoxal endite of same (right), external view; D, basis endite of same (right), external view; E, maxilla (right), external view; F, basis endites of same (right), internal view; G, coxal endite of same (right), internal view; H, maxilliped (right), external view; I, same, basis endite and basal joints of palp, (right), internal view; J, epipodite of maxilliped (left), internal view; K, uropod (left), dorsal view; L, caudal margin of pleotelson and basal part of uropod (left), dorsal view. A × 18, B × 85, C, D × 340, E × 135, F, G × 370, H, I × 100, J × 85, K × 41, L × 83.

geniculation intervening between carpus and propus. The basi-ischium is short, round, more or less crenated on the margin near the end as well as on the ventral side, and circumscribed by short flexible marginal and submarginal hairs. It is articulated to the body by the dorso-anterior angle and to the merus by the short ventro-anterior border. The merus is short and narrow, nearly quadrangular in side view and hinged by the whole dorsal edge with the basal part of the ventral border of the carpus. In addition to the crenation at the ventro-distal angle, the merus is furnished with marginal hairs similar to those of the basi-ischium. The carpus is broad, strongly elongated, more or less flattened, and is in contact at the basal edge with the basi-ischium. It has somewhat crenated ventral border, along which it is heavily fringed by very long setae as well as by shorter ones. It is also sparsely covered by short hairs on the dorsal side near the base and on the outer surface near the end. The propus which is somewhat shorter than the carpus has the fringe of long and short hairs arranged in a number of longitudinal rows on the ventral border, and is scattered on the outer surface by short hairs. The hand is relatively narrow, twice as long as broad and same time as long as the immovable finger. The latter is armed on its more or less undulated inner border near the apex with a number of sharp spinules besides with short hairs in the basal part, and ends in a stout blunt ungulus. The dactylus has a thick base attenuating toward the end which surpasses the immovable finger for a short distance. It is scarcely bent and armed with a low triangular bulge at about the middle of the inner border. Moreover, the dactylus is beset with short setae and ends in a stout ungulus which has a truncated apex and basal tubercles. The exopodite rudiment is very small, two-jointed, and arises from the terminal border of the basi-ischium close to the base of the carpus. The basal joint is longer than the apical joint which ends in two plumose hairs. The setae with which the cheliped is provided have frequently a few fringing hairs.

The first peraeopod is not fossorial, but ambulatory in function, being substantially of the same structure as the succeeding peraeopoda which are well flexible. This peraeopod consists of six slender joints and two-jointed exopodite rudiment. The basis is elongate, somewhat broader than in other peraeopoda, more or less crenated on the dorsal border which is produced just behind the end into a large recurved process with serrated margin. The dorsal border is fringed with short hairs, and has a small ciliated tubercle at the base of that process on the distal side. The ventral border, which is entire, and the outer surface are beset

Fig. 23. *Pagurapseudopsis gracilipes* gen. et sp. nov., female. A, cheliped (right), external view; B, chela of same (right), internal view; C, same, tip of immovable finger of chela (right), internal view; D, same, tip of dactylus (right), external view; E, basal part of cheliped (right), internal view; F, 1st peraeopod (right), external view; G, same (right), internal view; H, 2nd peraeopod (right), external view; I, distal part of same (right), external view; J, basis of same (right), external view; K, 6th peraeopod (right), external view; L, 3rd pleopod (right), posterior view. A, B × 41, C, D × 85, E-H × 52, I-K × 83.

Fig. 23.

with long flexible setae. The ischium is short, flexed dorsally in relation to the basis, and sparingly setose on two opposite borders. The merus is longer than the preceding, again bending dorsally. The carpus is further longer and subequal to the propus which is flexed ventrally. The merus and carpus are sparsely setose on two borders, the latter carrying a few feeble spines at the ventro-distal end. The propus has four spines along the ventral border and is encircled by a few similar spinules around the terminal border. The dactylus is somewhat curved ventrally like a sickle and ends in an elongate ungulus acuminating toward the sharp tip. The exopodite is two-jointed; the apical joint which is shorter than the basal ends in three long plumose setae.

The second to sixth peraeopoda are subequal in their size and similar to one another as well as to the first in their constitution except in the narrowness of the basis and in the lack of exopodite which the first possesses. In the second peraeopod the basis is armed with a series of small triangular dorsal teeth, the distalmost of which is better developed than others. The denticulation becomes more or less indistinct toward the posterior peraeopoda and is entirely obliterated in the last peraeopod. Setation of this joint and of the ischium is similar to that of the corresponding joints of the first peraeopod, but is somewhat more feeble in development. The merus bears a setae row on both margins. The ventral hairs on the carpus are replaced by spinules in the second to fifth peraeopoda, but are accompanied by a few setae on the sixth. The propus and dactylus of those legs are similar to those of the first peraeopod in shape and armatures.

The oostegites are not discernible.

The pleopoda are present in five pairs, very slender and somewhat decreasing in length toward the posterior pair. The protopodite of the pleopoda is elongate in an acicular form which is composed of short proximal and far longer distal joints; the latter joint is fringed by a small number of plumose setae on the inner border near the end. Exo- and endopodites are subequal in size, lanceolate, narrower than and half as long as the protopodite and marginated by several long plumose hairs.

Uropod is shorter than the antennule and a little longer than the abdomen. The peduncle is rod-like, about as long as the first three joints of the endopodite, and supplied with long setae on the external as well as on the terminal borders. The exopodite is thinner than the endopodite, to whose first four joints it equals in length, and consists of subequal, sparingly hairy joints. The endopodite is filiform, composed of 16 unequal joints and armed with zero to four hairs in each joint; the apical setae are longer than those of other joints.

Family Paratanaidae

Leptochelia longimana sp. nov.

(Figs. 24–25)

Occurrence: Station 294, depth 14 m, muddy sand bottom, at 9: 35, on March

25, 1960. One male, 3.2 mm × 0.6 mm. Station 307, depth 4 m, fine sand bottom, at 9: 20, on March 30, 1960. One male, 3.0 mm × 0.5 mm. Station 327, depth 7 m, fine sand bottom, at 9: 35, on April 4, 1960. Seven males. 2.4 mm × 0.4 mm, 2.8 mm × 0.5 mm, 2.9 mm × 0.5 mm, 2.9 mm × 0.5 mm, 3.1 mm × 0.5 mm, 3.1 mm × 0.6 mm and 3.4 mm × 0.6 mm. The largest female from Station 327 was dissected.

Male: Body is cylindrical rather than depressed and almost uniform in width throughout the entire body. 3.4 mm × 0.6 mm. It is colorless, transparent and without any pigment except that of eye.

The carapace exceeds a quarter of the body length, and is wider posteriorly than anteriorly, somewhat abruptly widening a little in front of the middle of its length. The fore margin is gracefully arched, with a very slight median angulation, and depressed at the extreme lateral ends to form a pair of sinuses into which the oval eye lobes are inserted. The sides of the carapace are parallel in the anterior region, but swollen in the posterior region. The posterior border is curved backward. Eyes are normal and darkly pigmented.

The thorax occupies about a half of the entire body. The first two peraeomeres are equal in length and the shortest of all, the third and sixth, being subequal to each other, come next, and the fourth and fifth, again subequal, are the longest. In the shortest peraeomeres, the length does not surpass a third of the width, in those with a medium length the former attains a half of the latter, and finally in the longest somites, the former exceeds two-thirds of the latter. All the peraeomeres are continuous and entire on the sides, and are raised in a low elevation on the mid-ventral line. The last somite bears a pair of mammiform gential processes on the sternum.

The abdomen is a little less than a quarter of the entire body, only slightly narrowed toward the rear, and crowded with five pleomeres and pleotelson. The pleomeres are all of equal length, transversely linear, and round on the sides. The pleotelson is as long as the preceding two pleomeres combined together, and twice as wide as it is long. It has widely round caudal margin which is produced on the median into a pointed bulge. In general, the posterior region of body is sparingly setose.

Antennules of both sides are close to each other on the midline. Each of them is excessively long, longer than the body and composed of elongated, three-jointed peduncle and short six-jointed flagellum which attains merely to one fifth the length of the peduncle. The first two joints of the peduncle are very slender and elongate, the first joint surpassing the second, whereas the third joint is strongly reduced, exceeding the first flagellar joint only a little. The joints of the flagellum are narrowed gradually toward the end, but subequal in length to one another. All of the joints have a few short setae at their ends.

Antenna is short, shorter than the first joint of the antennule and six-jointed. The first joint is very short, the second reaches more than twice the length of the first, while the third is again somewhat shortened. The fourth joint, the longest

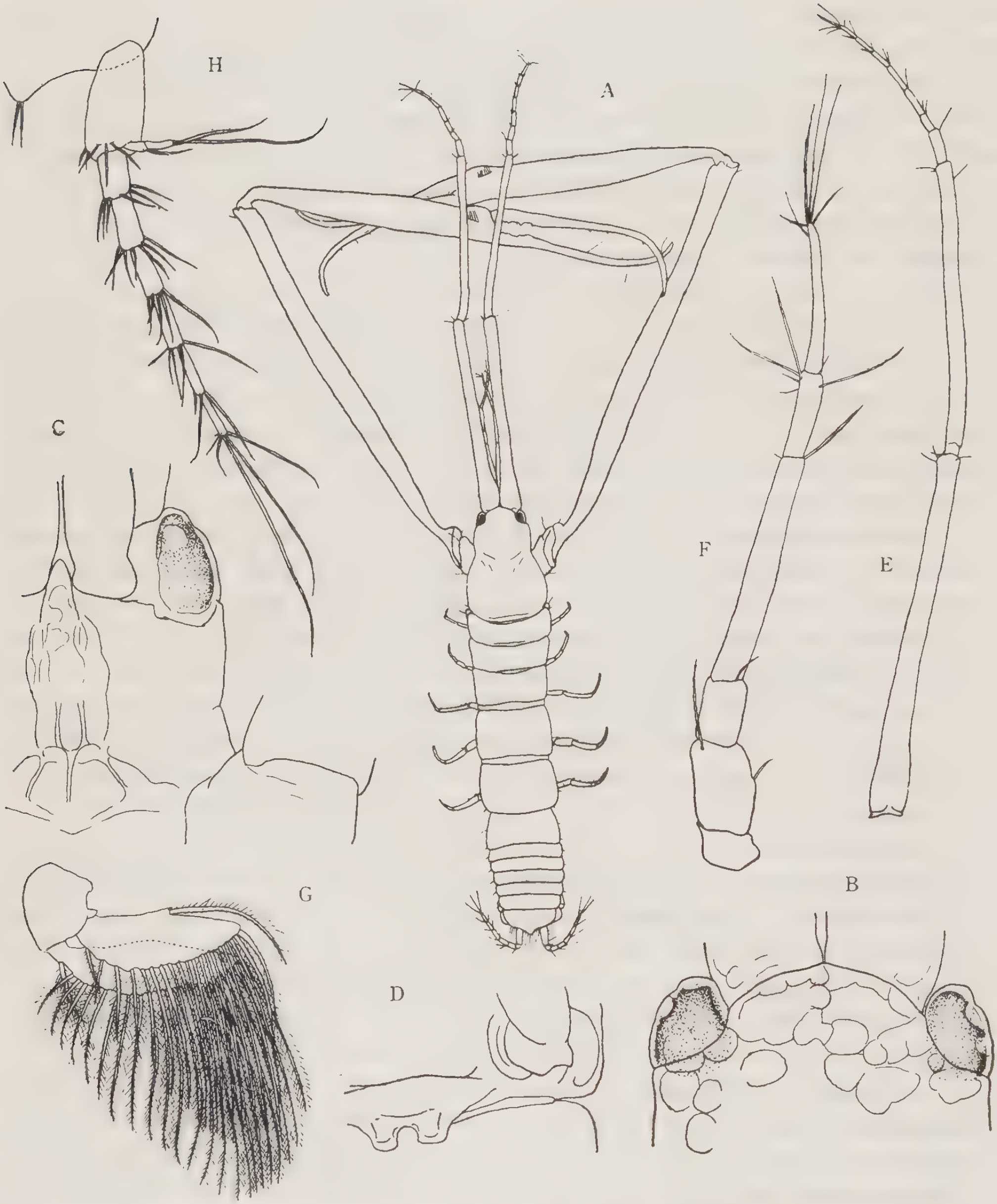

Fig. 24. *Leptochelia longimana* sp. nov., male. A, male, dorsal view; B, fore end of carapace, dorsal view; C, fore end of cephalothorax, left half, ventral view; D, 6th peraeomere, left half, showing genital papillae, ventral view; E, antennule (left), dorsal view; F, antenna (right), ventral view; G, 1st pleopod (left), posterior view; H, uropod (left), ventral view. A × 18.5, B, D, G, H × 120, C, F × 83, E × 34.

of all, is longer than the combined length of the basal three joints, and as long as that of the apical two joints. Of these, the sixth joint is longer than the fifth, and

the both are armed with a number of terminal setae in contrast to other joints which are very scarce in hairs.

Mouth parts are reduced.

Cheliped is developed into an excessively elongate limb attaining to twice the length of the body and is bent once at the articulation between carpus and propus. The basi-ischium is short, curved near the attachment to the body, and receives the merus and carpus on the terminal truncate border. The merus is a small triangle attached to the inner side of the base of the propus. The carpus is a strongly elongate, straight style which reaches the length of body. It is strongly narrowed near the base, then broadening, gradually but slightly attenuates from the middle to the end. The propus is as long as the carpus. It has a narrowed base and surpasses the carpus in width in the widest region. The immovable finger occupying less than a half of the length of the propus is very slender, incurvated near the apex and has five or six denticles irregularly disposed near the base of the inner border. The hand bears a short oblique row of closely standing short spinules on the inner surface near the base of the dactylus. The dactylus is a little longer than the immovable finger and shows a stronger terminal curve. It is sparsely setose on the inner border besides carrying four or five denticles near the base. The apices of the two fingers of the chela cross each other. This appendage is scattered by short setae, especially on the carpus and on the finger of the propus.

The succeeding peraeopoda are short, slender, more or less alike, and have the ischium well differentiated. The first two peraeopoda are inserted to the anterior angle of the respective somites, the third to the middle and the rest near the posterior angle. Geniculation is interposed between ischium and merus, and between propus and dactylus. In all of them, the basis is the longest of all the constituent joints, and the ischium is very short, while the others being moderately long. The dactylus is variable in length according to the peraeopoda.

The first peraeopod is different from others in that the dactylus is elongated into a slender, sharply pointed, sickle-like joint, in which the limit of the terminal ungulus is obliterated. The carpus and propus bear a small number of setae encircling the subterminal region. The basal three joints are scattered by a few feeble hairs. In the second and third peraeopoda which are alike, the dactylus is shorter, stumpy and has the ungulus distinctly delimited from the joint. The terminal setae on the merus and carpus are partly reduced, or replaced by spines. The merus has a single ventral spine and the carpus has another on the anterior side. In the last three peraeopoda, these spines are increased to two on the merus and to five on the carpus, two of these locating on the outer side and three on the inner side. The propus has a single ventral spine also. The dactylus is proportionately longer than in the preceding peraeopoda.

Pleopoda are present in five pairs. The protopodite is short and unarmed. The two rami, resembling each other in size and structure, are crescentic lamellae which are heavily fringed by plumose setae only on the external border except for

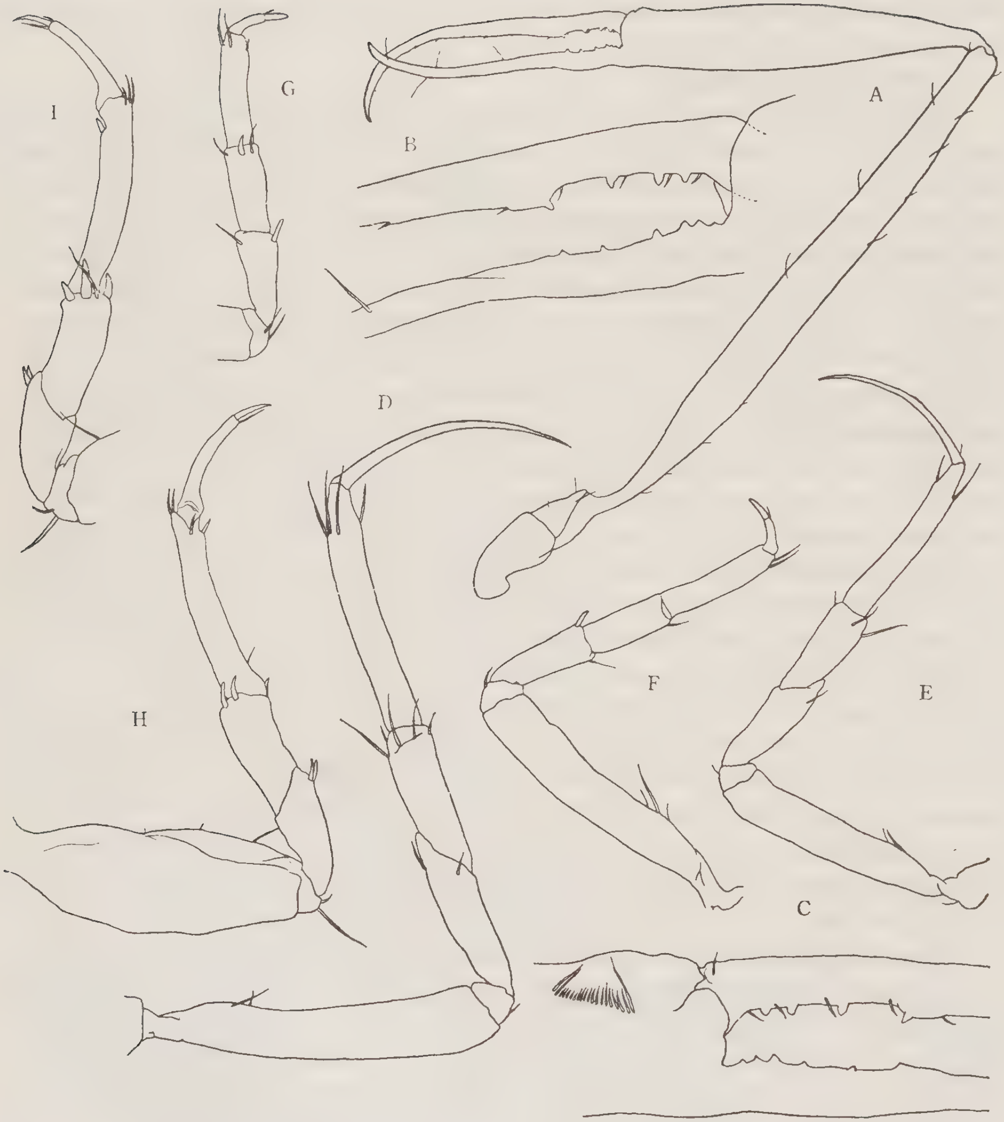

Fig. 25. *Leptochelia longimana* sp. nov., male. A, cheliped (left), dorsal view; B, same, basal part of thumb and finger of chela (left), ventral view; C, same part (left), dorsal view; D, 1st peraeopod (left), internal view; E, same (left), external view; F, 2nd peraeopod (left), external view; G, same, from ischium to dactylus (left), internal view; H, 4th peraeopod (left), external view; I, same (left), from ischium to dactylus, internal view. A × 127, B, C, E × 83, D, F–I × 120.

a single solitary one arising from the middle of the inner border of the endopodite.

Uropod is shorter than the abdomen. The peduncle is thick, one-jointed, and circumscribed by a number of setae at the end. The endopodite comprises six subequal joints which are gradually narrowing toward the tip. Besides the apical

tuft of setae, the endopodite is encircled by a number of setae at the end of each joint. The exopodite is very short, narrow, about as long as the first joint of the endopodite and consists of two equal joints. The apical joint terminates in long setae, while the basal joint has only a single short one.

Remarks: The present species is very closely allied to *Leptochelia minuta* Dana and *L. erythraea* (Kossmann) in the possession of exceedingly long chelipeds and in that the uropoda have six-jointed endopodite and two-jointed exopodite. It shows a closer resemblance to *L. erythraea* which was once synonymized by Stebbing (1900) with *minuta*, but kept distinct by Nobili (1907), Monod (1933) and Larwood (1954). The last author, in redescribing *erythraea*, enumerated some important differences of this species from *minuta*. According to him, in *erythraea* "(1) the superior antennae are not as long as the body, (2) the third segment of this appendage is more than half the length of the second, (3) the carpus of the cheliped is not parallel-sided but has a slight emargination towards the base, (4) there is no low prominence near the apex of the thumb of the cheliped, and (5) the uropods are certainly not equal in length to the pleon". Of these point, the last three are applicable to the case of the comparison between *minuta* and the new species. The antennules of the new species, however, are longer than the body and the third joint of the antennae is much reduced, the second joint being elongated far more than in both of the known species. The chelipeds, which are alike those of *minuta* in the slenderness, are relatively far slenderer and longer than in *erythraea* and have no subterminal protuberance on the propus of *minuta*. Further, the chelipeds of the new species have basal denticles, which are absent from both of the known species, on the inner borders of thumb and finger of the chela.

Putting this and that together, we might be led to believe that those three species might represent the local variations of one and the same species. At present, however, it may be wiser to regard them distinct, in so far as nothing is known about the intermediate forms which may link them up one with another.

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The Type or Authentic Specimens of *Gelidium* in Europe

Toshio Segi

(With Plates I–LII)

In Japan so-called *Tengusa* which are most important useful algae have been hitherto identified with various species of *Gelidium*, by comparing with the foreign species. In identifying, however, it is often difficult to determine accurately, basing on only the descriptions or figures. It is necessary to examine actually the type or authentic foreign specimens. Under such circumstances, the writer had favourable opportunities for going abroad in 1950, 1958 and 1961. He examined and photographed for himself as many type or authentic specimens in various European and American herbaria as possible. Some of them were old, rather fragment ones and it was impossible to observe or photograph them completely. In some degree, however, the important outward appearances and inner characters have been cleared by his study. The present paper first deals with the photographs of the type or authentic specimens of *Gelidium* preserved in European herbaria. Because of limited pages, there are other photographs unprinted on this paper. In this paper 55 species and 14 varieties of *Gelidium* are enumerated. Sometimes he was obliged to take pictures under difficult conditions there. According to indistinctive letters written on the boards or labels of the specimens, it is considered that there may be some incorrect spellings in the explanation of the specimens on this paper. Although the photographs of specimens are thus imperfect, if the present paper would give some help to the systematic study of the species of *Gelidium*, which abound on the coast of Japan, the writer will be pleased.

His sincere thanks are due to Mrs. Butler, British Museum (Natural History), London, Dr. Christensen, Botanical Laboratory, University of Copenhagen, Copenhagen, Dr. Demaret, National Botanical Garden, Brussels, Miss Dickinson in Herbarium of Royal Botanic Gardens, Kew, London, Prof. Feldmann in Oceanographic Institute, University of Paris, Dr. Meslin in University of Caen, France, Dr. Bourrelly and Miss André in Laboratory of Cryptogamy, National Museum of Natural History, Paris, Dr. Henderson, Dr. Green and Miss Prentice in Botanic Laboratory, Royal Botanic Garden, Edinburgh, Dr. Koster in Rijksherbarium, Leiden, Holland, Mrs. Kylin and Dr. Peterson in Botanical Museum, University of Lund, Lund, Sweden, for their kind assistance and permissions to examine their precious herbaria.

Explanation of the specimens

Gelidium aculeatum BATTERS
(Plate I ×ca. 1)

The specimen is enveloped in the type cover with two red lines thereon, which is noted with "*Gelidium corneum* var. *aculeatum* GREV. in GREV., Algae Brit. P. 143, Herb. HORT. EDIN."

The frond is small, attaining to ca. 3.5 cm. high, cartilaginous and does not adhere to paper in drying. It is reddish brown in colour, rough in the substance and pinned to the paper in drying (Royal Botanic Garden, Edinburgh).

Gelidium amansii LAMOUROUX
(Plate II, A slightly reduced)

The type specimen was shown already in the previous paper (SEGI, Type specimens of *Porphyra tenera* and *Gelidium amansii* in Rep. Fac. Fish., Mie Univ, vol. 3, No. 2, XI, 1959, p. 251, pl. X).

The specimen (Plate II, A) was collected in Yokohama and used in KÜTZING, Tab. Phyc. XVIII, 44 (Rijksherbarium, Leiden).

Gelidium arbusculum BÖRGESEN
(Plate II, B slightly reduced)

The explanation of the specimen is shown as follows: Algae marinae Canarienses, *G. arbusculum* BÖRG., Type, det. F. B., leg. F. BÖRGESEN, anno 1921, No. 3253, Insula Tenerife, Orotava 20/1 (Botanical Museum, Copenhagen).

Gelidium asperulum KÜTZING
(Plate II, C slightly reduced)

The explanation of this specimen is shown as follows: "Rhodophyceae 40, Austral., Herb. Lugd. Bat. N. 941, 51…6 (brownish label); Herbarium KÜTZING "Type !" (red paper), *Gelidium asperulum* KG. Tab. Phyc. XVIII, 43, Neuseeland, HOOKER (Rijksherbarium, Leiden).

Gelidium attenuatum THURET
(Plate III, A ×ca. 1)

This specimen is preserved in British Museum (Natural History), London.

Gelidium aureum AGARDH
(Plate III, B ×ca. 1)

The explanation of this specimen is shown as follows: Herb. WEBER-VAN BOSSE,

"Herb. Lugd. Bat. 10. Eur. As. No. 941, 46…413 (yellowish label)", Rhodophyceae; Herb. W. F. R. SURINGAR. The letters, "Dalmatia, 1840, v. Vrellner (?)" is signed on the lower part of this specimen (Rijksherbarium, Leiden).

Gelidium australe J. AGARDH
(Plate IV ×ca. $\frac{2}{3}$)

The red label, "Typus !" is attached to this specimen. The explanation is shown as follows: e Port Phillip F. or Muclud (?), G. Australe, No. 33188 (No. 33179–No. 33195).

The frond is finely branched and covered with some spinous ultimate branchlets on the branch. It is faded in colour and represents yellowish green in the upper part of it. In the other part it is pale, reddish purple and rather yellowish brown in colour. This does not adhere to paper in drying (Botanical Museum, Lund).

Gelidium biserratum BÖRGESEN
(Plate V ×ca. 1)

The explanation of this specimen is shown as follows: *Gelidium biserratum Börgs*', Mauritius, Fig. 2, F. BÖRGESEN, Det. Original Exemplar (Type!) (Botanical Museum, Copenhagen).

Celidium cartilagineum (LINNÉ) GAILLON
(Plate VI, VII ×ca. $\frac{1}{2}$)

The specimen of Pl. VI is covered by red genus cover. There are 11 fronds on one board.

In general the frond of Pl. VII shows a resemblance to that of *Gelidium pacificum* OKAMURA in Japan. This specimen is very large and so photographed in two parts separately (Royal Botanic Gardens, Kew).

Gelidium caulacantheum J. AGARDH
(Plate VIII, A ×ca. 1)

The frond of this specimen (No. 32818) is finely branched in rather irregular manner. It is rigid, cartilaginous and reddish purple in colour. It is somewhat adhering to paper in drying (Botanical Museum, Lund).

Gelidium coarctatum KÜTZING
(Plate VIII, B, IX, A ×ca. 1)

The fronds of Pl. VIII, B (No. 850) and Pl. IX, A (No. 851) are attached on one paper noted with "Côtes De Pernambuco". The explanation of the specimen is shown as follows: Herb. WEBER-VAN BOSSE, "Herb, Lugd. Bat. 60, Amer. Merid. No.

941, 45…42 (pinkish label)"; Rhodophyceae, Herbarium Kütz, "Type" (red paper) (Rijksherbarium, Leiden).

Gelidium coerulescens KÜTZING
(Plate IX, B ×ca. 1)

The explanation of the specimen is shown as follows: Herb. Weber-van Bosse!, "Herb. Lugd. Bat. 40 Austral. No. 941, 11…91 (brownish label)"; Rhodophyceae, Herb. Kützing; Type ! (pinkish paper) (Rijksherbarium, Leiden).

Gelidium corallinum KÜTZING
(Plate X ×ca. 1)

The explanation of the specimen is shown as follows: Herb. Weber-van Bosse; "Herb. Lugd. Bat. 40, Austral. No. 941, 11…8 (brownish label)"; Rhodophyceae, Herbarium Kützing; "Type !"; Herbarium Kützing; *Gelidium corallinum* Kg. Tab. Phyc. XVIII, 56, Neuseeland F. D. Hooker (Rijksherbarium, Leiden).

Gelidium corneum LAMOUROUX
(Plate XI, A, B, XII, ×ca. 1; XIII, slightly reduced)

The frond of Pl. XI, A is fine, rigid membranaceous, reddish brown in colour. It does not adhere to paper in drying (National Museum of Natural History, Paris).

The explanation of the frond of Pl. XI, B is shown as follows: Herb. Weber-van Bosse, "Herb. Lugd. Bat. 10, Eur. As. No. 941, 46…293", Rhodophyceae, Herb. Kützing (Rijksherbarium, Leiden).

The frond of Pl. XII is rigid membranaceous and reddish purple in colour and does not adhere to paper in drying (National Museum of Natural History, Paris).

The specimen of Pl. XIII is material used in Turner, Fuci, Vol. IV, P. 148, pl. 257, a, d, f, m, p, q (Royal Botanic Gardens, Kew).

var. **ceylanicum GRUNOW**
(Plate XIV, A ×ca. 1)

The frond is membranaceous and reddish brown in colour. It does not adhere to paper in drying (National Museum of Natural History, Paris).

var. **clavatum AGARDH**
(Plate XIV, B, C ×ca. 1)

This specimen (Pl. XIV, B) is attached on the board signed as "Kew 217". It is enveloped by the cover noted "New Zealand & Austr." (Royal Botanic Gardens, Kew).

Four envelopes including specimen respectively are attached on one board.

The specimen (Pl. XIV, C) which is preserved in upper most envelope is considered as type. The explanation is shown as follows: *Gelidium corneum* (Huds.) Lamx. var. *clavatum* Ag. No locality, ex Herb. Hudson comm. D. Lambert Meryies Herbarium, Type of *Fucus corneus* Hudson fide Hudson. (Royal Botanic Garden, Edinburgh).

var. **pinnatum** **Greville**
(Plate XV, A × ca. 1)

The explanation of the specimen is shown as follows: *Gelidium corneum* (Huds.) Lamx. var. *pinnatum* Grev. *Sphaerococcus corneus* var. (?) *pinnatum* ad Gades Agardh, Spain, Greville Colln. (Royal Botanic Garden, Edinburgh).

var. **pristoides** **Greville**
(Plate XV, B, C × ca. 1)

The frond of the specimen (No. 999, Pl. XV, B) is rigid membranaceous, dark reddish brown in colour and somewhat adhering to paper in drying.

The frond of the specimen (No. 1008, Pl. XV, C) is the same as the former, but it is finely branched and does not adhering to paper in drying (National Museum of Natural History, Paris).

var. **proliferum** **Greville**
(Plate XVI, A, B × ca. 1)

The specimen (Pl. XVI, A) is preserved in Royal Botanic Garden, Edinburgh.

The frond of the other specimen (Pl. XVI, B) is rigid membranaceous, reddish brown or greenish brown in colour. It does not adhere to paper in drying (National Museum of Natural History, Paris).

var. **pulchellum** **Greville**
(Plate XVII, A × ca. 1)

This specimen is signed var. λ *pulchellum* (Royal Botanic Gardens, Kew).

var. **pulvinatum** **Agardh**
(Plate XVII, B × ca. 1)

The explanation of the specimen is shown as follows: *Gelidium corneum* (Huds.) Lamx. var. *pulvinatum* Ag. Gades Spain ! Greville Colln. (Royal Botanic Garden, Edinburgh).

var. **sesquipedale** **Greville**
(Plate XVIII, A, B × ca. $\frac{2}{3}$)

The frond of the specimen (Pl. XVIII, A) is rigid membranaceous, yellowish

brown in colour. It does not adhere to paper in drying (National Museum of Natural History, Paris).

The frond of the specimen (Pl. XVIII, B) is preserved in Royal Botanic Gardens, Kew.

var. **setaceum** KÜTZING
(Plate XIX ×ca. $\frac{2}{3}$)

The label of this specimen is shown as follows: "Herb. G. THURET, *Gelidium corneum* LAMOUROUX, var. *Setaceum* KÜTZING, Golfe d'Aden, 1885–86."

The frond is coarse, rigid membranaceous in the substance. It is brown in colour. It does not adhere to paper in drying (National Museum of Natural History, Paris).

var. **subtile** GREVILLE
(Plate XX, A ×ca. 1)

The frond is rigid membranaceous, yellowish brown in colour. It does not adhere to paper in drying (National Museum of Natural History, Paris).

var. **verruculosum** GREVILLE
(Plate XX, B ×ca. 1)

The frond is rigid membranaceous, dark green in colour. It does not adhere to paper in drying (National Museum of Natural History, Paris).

Gelidium crinale (TURNER) LAMOUROUX
(Plate XXI, A–F ×ca. 1)

This specimen (Plate XXI, A) is No. 32765 (No. 32743–32771 in Botanical Museum, Lund). The frond is fine, rigid, stout and reddish brown in colour. It does not adhering to paper in drying.

The explanation of the specimen (Plate XXI, B) is shown as follows: Herb. WEBER-VAN BOSSE, "Herb. Lugd. Bat. 10. Eur. As. No. 941, 46…75 (Yellowish Label)"; Rhodophyceae, Herb. KUETZING, Type van *Acrocarpus corymbosus* KG. In this cover there is a paper written "These specimens have been used for Tab. Phyc. XVIII, 1868, t. 36–a–c."

The explanation of the specimen (Pl. XXI, C) is shown as follows: "Type van *Gelidium Polycladum* KUTZ (pinkish label)"; Tab. Phyc. XVIII, 55. M. Adriat. Robenhorst.; Herb. WEBER-VAN BOSSE; "Herb. Lugd. Bat. 10. Eur. As No. 941, 46…123 (yellowish label)", Rhodophyceae, Herb, KÜTZING.

On the specimen (Pl. XXI, D) there is a sign "*Acrocarpus spinescens* KG., Venezia (?), This specimen has been used for Tab. Phyc. XVIII, 1868, t. 33, d–e". The

explanation of the specimen is shown as follows: Herb. WEBER-VAN BOSSE, "Herb. Lugd. Bat. 10. Eur. As, No. 941–46–74 (yellowish label), Rhodophyceae, Herb. KUETZING.

The explanation of the specimen (Plate XXI, E) is shown as follows: *Acrocarpus crinalis* KG. Tab, Phyc. XVIII, 33, Sicilia, Herb. KÜTZING, Herb. WEBER-VAN BOSSE, "Herb. Lugd. Bat. 10 Eur. As. No. 941, 46···97 (yellowish label)".

The explanation of the specimen (Pl. XXI, F) is shown as follows: *Gelidium crinale*, *Acrocarpus crinalis* KG. 3, Tab. phyc. XVIII, 33 ! (Rijksherbarium, Leiden).

Gelidium decidum DAWSON
(Plate XXII, A ×ca. 1)

The explanation of the specimen is shown as follows: "Type Dupl" (pinkish label); "Herb. Lugd. Bat. 50 Amer. Sept. No. 955, 62···26 (reddish label)"; Smithsonian Institution from the United States National Herbarium; *Gelidium decidum* DAWSON, sp. nov. Isotype, Mexico: Cabeza Ballena, near cabo San Lucas, Baja California, On granite reef with many tide pools. Temp. 2660. E. YALE DAWSON 3413, November 9, 1949 (Rijksherbarium, Leiden).

Gelidium dicranemum SURINGAR
(Plate XXII, B ×ca. 1)

The explanation of the specimen is shown as follows: "Herb. Lugd. Bat. 10. Eur. As., No. 943, 85···34 (faded brownish label);" Rhodophyceae, *Gelidium Dicraneum* SURING. e Japonia, Herbarium W. F. R. SURINGAR (Rijksherbarium, Leiden).

Gelidium divaricatum MARTENS
(Plate XXIII, A, B, C ×ca. 1)

The explanation of the specimen (Pl. XXIII, A) is shown as follows: *Gelidium divaricatum* Hong Kong v. MARTENS.

The explanation of the specimen (Pl. XXIII, B) is shown as follows: "Tange V Ost-Asien p. 30, t. VIII, Fig. 4 Nom. Jap. *Himotengusa*, OKAMURA, Watanoha (Rikuzen) July 1897" (Rijksherbarium, Leiden).

The explanation of the specimen (Pl. XXIII, C) is shown as follows: "Herb. Crypt. Mus. Paris, *Gelidium Divaricatum* MARTENS"; "K. OKAMURA-Algae japonicae Exsiccatae, 4. *Gelidium divaricatum* MARTENS, Tange V Ost-Asien p. 30 t VIII, Fig. 4. Nom. Jap: *Hime-tengusa* OKAMURA Watanoha (Rikuzen) July, 1897. The fronds of this specimen are brownish and reddish purple in colour and do not adhere to paper in drying (National Museum of Natural History, Paris).

Gelidium elegans KÜTZING
(Plate XXIII, D ×ca. 1)

The pinkish label "Type" is attached to this specimen collected by MARTENS. The explanation of the specimen is shown as follows: Herb. WEBER-VAN BOSSE, "Herb. Lugd. Bat. 10. Eur. As. No. 941, 46…342" (Rijksherbarium, Leiden).

Gelidium fasciculatum HAMEL
(Plate XXIV, A slightly reduced)

On this specimen there is a sign "La Guardia September 1927, Les Algues de Vigo (Extrait de la Revue Algologique, année 1928) p. 90–91. The frond does not adhere to paper in drying (Herb. FELDMANN, Paris).

Gelidium flaccidum DANGEARD
(Plate XXIV, B slightly reduced)

The explanation of the specimen is shown as follows: "Herb. Crypt. Mus. Paris *Gelidium Flaccidum* P. DANGEARD, Date: a juillet 1940".

The frond is membranaceous, reddish brown in colour and does not adhere to paper in drying (National Museum of Natural History, Paris).

Gelidium foliosum DANGEARD
(Plate XXIV, C slightly reduced)

The frond is fragile, membranaceous, reddish brown in colour, and does not adhere to paper in drying (National Museum of Natural History, Paris).

Geildium harveyanum GREVILLE
(Plate XXV, A, B ×ca. 1)

The specimens (Pl. XXV, A, B) are put into the envelope noted "Ceylon 1888 leg. W. FERGUSON". On the frond of the specimen (Pl. XXV, A) there are many blackish parts (Royal Botanic Garden, Edinburg).

Gelidium heteroplatos BÖRGESEN
(Plate XXVI, A, B ×ca. 1)

The specimen (Pl. XXVI, A) was used in BÖRGESEN's paper (Botanical Museum, Copenhagen).

Gelidium hildebrandtii (HAUCK) SCHMITZ
(Plate XXVII slightly reduced)

The explanation of the specimen is shown as follows: *Thysanocladia Hildebrandtii* H., Mombassa, juli 1867 n. sp. lg. HILDEBRANDT. The plate is shown as a lower half part of the frond (Rijksherbarium, Leiden).

Gelidium intertextum DANGEARD
(Plate XXVIII, A ×ca. 1)

The frond is fine, fragile, reddish purple in colour. It does not adhere to paper in drying (National Museum of Natural History, Paris).

Gelidium latifolium BORNET
(Plate XXVIII, B ×ca. 1; XXIX slightly reduced;
XXX, XXXI, A, B, C, XXXII, A ×ca. 1)

The explanation of Pl. XXVIII, B is the same as that in the label of Pl. XXIX. The frond is rigid membranaceous, reddish purple in colour and does not adhering to paper in drying.

The fronds of Pl. XXIX, XXX are rigid membranaceous, reddish brown in colour and do not adhere to paper in drying.

On the specimen (Pl. XXXI, B, C) there is a sign "Antibes ! 25 November 1855" respectively. The fronds of the specimen (Pl. XXXI, A, B, C) are rigid membranaceous, reddish brown in colour and do not adhere to paper in drying (National Museum of Natural History, Paris).

The specimen of Pl. XXXII, A is covered by red cover noting "Al. Rh. 38. 275" (Royal Botanic Gardens, Kew).

var. **hystrix** J. AGARDH
(Plate XXXII, B ×ca. 1)

On this specimen there is a sign "Type !, van *Eckinocaulon strigosum* KÜTZ." The explanation of the specimen is shown as follows: Herb. W. v. BOSSE; "Herb. Lugd. Bat. 10 Eur. As., No. 941, 46···247 (yellowish label)"; Rhodophyceae, Herbarium KÜTZING, Rijksherbarium L. 1528, No. 7 (Rijksherbarium, Leiden).

Gelidium lingulatum J. AGARDH
(Plate XXXII, C, XXXIII, A, B ×ca. 1)

There are specimens from No. 33240 to No. 33242. On the specimen (Pl. XXXII, C, No. 33241) there is a sign "Typus". The frond is rather simple. On the upper and middle part of the frond it is issuing, more or less short spinuous branchlets. It is rigid, compressed, reddish purple in colour and does not adhere to paper in drying (Botanical Museum, Lund).

Gelidium linoides KÜTZING
(Plate XXXIII, C ×ca. 1)

The explanation of the specimen is shown as follows: Herb. WEBER-VAN BOSSE; "Herb. Lugd. Bat. 10 Eur. As., No. 941, 46···449", Japan. Tab. Phyc. XVIII, 58,

Herb. Kützing, Rijksherbarium L. 1647, No. 258 (Rijksherbarium, Leiden).

Gelidium longipes J. Agardh
(Plate XXXIV ×ca. ½)

There are specimens from No. 32805 to No. 32808. The explanation of this specimen is shown as follows: Bay of Ilands, Nova. Zelandiae, Berggren, *Gelidium longipes* J. Ag. The frond is fine, rigid and fibrous. On the upper part of it is reddish purple and on the lower faded, yellowish green in the colour (Botanical Museum, Lund).

Gelidium multicorne Kützing
(Plate XXXV, A ×ca. 1)

The explanation of the specimen is shown as follows: "Type !" (pinkish label); Tab. Phyc. XVIII, 66; Herb. Weber-van Bosse; "Herb. Lugd. Bat. 40 Austral. No. 941, 11...92 (brownish label)"; Rhodophyceae, Herb. Kützing, N. Caledonia, Vieillard (Rijksherbarium, Leiden).

Gelidium nudifrons Gardner
(Plate XXXV, B ×ca. 1)

The explanation of the specimen is shown as follows: "Herb. Lugd. Bat. 50 Amer. Sept. No. 952, 85, 166 (reddish label)"; Rhodophyceae, Algae, distributed by the Allan Hancock Foundation; The University of Southern California; "Marine Algae of Pacific Mexico, Hancock-Guggenheim Expedition, of 1946, *Gelidium nudifrons* Gard.; Locality: Punta Santa Rosalia, April 13, 1946; Habit: Rocky shore with heavy surf and almost no tide pools. Temp. 16.2° on all sides of point. Nos; 1482–1521 from beach drift on Sandy beach inside point Collected by E. Y. Dawson, det. by E. Y. Dawson, No. 1502". The frond shows a resemblance to *Gelidium linoides* Kützing in Japan (Rijksherbarium, Leiden).

Gelidium parvulum Greville
(Plate XXXV, C ×ca. 1)

The specimen is put into the envelope noted "Greville Collection Brazil St. Hibaire (?) 1832". There is a label noted "1726 *Gelidium parvulum* Grev." and the description of this frond (Royal Botanic Garden, Edinburgh).

Gelidium pectinatum Montagne
(Plate XXXVI ×ca. ¾)

This specimen is aged and so satained on various parts of it. The frond is reddish brown in colour and adhere to paper in drying (National Museum of Natural

History, Paris).

Gelidium pinnatifidum (J. AGARDH) SCHMITZ
(Plate XXXVII, × ca. 1; XXXVIII, slightly reduced)

On the left corner of the specimen (Pl. XXXVII) there is a sign "South Africa, The Kowie 14 Feb. 1894, Dr. H. BECKER". The explanation of this specimen is shown as follows: Herb. WEBER-VAN BOSSE; "Herb. Lugd. Bat. 30 Africa, No. 938, 316…70, Rhodophyceae (light blue label)". Algae Marinae Africae Australis, The Kowie, H. BECKER M. D., F. L. S. *Gelidium* (SCHMITZ) *Pinnatifidum* J. AG., *Ptilophora pinnatifida* J. AG. Till Algern. System IV, 79 (Pl. XXXVII in Rijksherbarium, Leiden, Pl. XXXVIII in British Museum, Natural History, London).

Gelidium pristoides (TURNER) KÜTZING
(Plate XXXIX A, B slightly reduced; XL × ca. 1)

The explanation of the specimen (Pl. XXXIX, A) is shown as follows: *Gelidium pristoides* (TURN.) KUETZ. Wynberg?, False Bay, Cape of Good Hope, 1835/6 GREVILLE Colln. (Royal Botanic Garden, Edinburgh). The frond resembles to *Gelidium japonicum* OKAM., though it is rather slender than the latter. It is cartilaginous, purplish brown in colour and does not adhere to paper in drying.

The note on the specimen (Pl. XXXIX, B) is shown as follows: *G. pristoides* is distinguished from *Suhria japonica* by the sharply toothed frond. The form of the sporophyll see Herb. spec. (Royal Botanic Gardens, Kew).

The explanation of Pl. XL is shown as follows: Herb. WEBER-VAR BOSSE, "Herb. Lugd. Bat 30 Africa. No. 938, 316…197". Rhodophyceae, Herb. W. F. R. SURINGER (Rijksherbarium, Leiden).

Gelidium proliferm HARVEY
(Plate XLI × ca. 1)

This specimen is enclosed in the envelop noted "Herb. WIGHT propr. *Gelidium proliferm* GREV., Peninsula Ind. orientalis, GREVILLE Colln."

The lower specimen is less branched and rather simple, cartilaginous, coarse and not adhering to paper in drying (Royal Botanic Garden, Edinburgh).

Gelidium pulchellum (TURNER) KÜTZING
(Plate XLII, A slightly reduced)

The explanation of the specimen is shown as follows: *Gelidium pulchellum* KÜTZ. Recueilli par M. C. SAUVAGEAU a san vicente de La Barquera (Espagne) Le 7 Septembre 1896. On the upper right corner of it there is the sign "S. Vicente La Barquera" (British Museum, Natural History, London).

Gelidium pulchrum GARDNER
(Plate XLII, B slightly reduced)

The label is shown as follows: Herbarium of the University of California, Algae of California, *Gelidium pulchrum* GARDNER, Middle Littoral belt, Two miles south of Balboa, Orange County, N. L. GARDNER 2423 a, 10. April 1911 (Royal Botanic Gardens, Kew).

Gelidium pulvinatum THURET
(Plate XLIII, A, B ×ca. 1)

The frond (Pl. XLIII, A) is massed, dark reddish brown in colour and does not adhere to paper in drying.

The frond (Pl. XLIII, B) is massed, fragile, coarse, dark reddish brown in colour and does not adhere to paper in drying (National Museum of Natural History, Paris).

Gelidium purpurascens GARDNER
(Plate XLIV ×ca. 1)

The explanation of the specimen is shown as follows: Algae Distributed from the Herb. of the Univ. of Calif. 241. *Gelidium purpurascens* GARDNER, Moss Beach, San Matio County, California, The type locality, N. L. GARDNER No. 6256 April 1927 (Royal Botanic Gardens, Kew).

Gelidium pusillum (STACKHOUSE) LE JOLIS
(Plate XLV, A–E, XLVI A ×ca. 1)

The label of the specimen (Pl. XLIV, A) is shown as follows: "Herbier du Jardin botanique de l'État, Bruxelles, Herb. J. CHALON 1812–18, Acc. 1910." The frond is massed, reddish, brownish purple and does not adhere to paper in drying.

The label of the specimen (Pl. XLV, B) is shown as follows: 2004, "Herbier du Jardin botanique de l'État, Bruxelles, *Gelidium pusillum* (STACKH.) LE JOL., HAUCK loc. cit." The character of the frond is the same as that of Pl. XLV, A (National Botanical Garden, Brussels).

The specimen (Pl. XLV, C) noted "Cherboury 8 nov. 1881" is preserved in Botanical Museum, Copenhagen.

The sign "Herb. J. CHALON 1812–18 Acc. 1910" is added to the upper label of Pl. XLV, D.

The explanation of the specimen (Pl. XLV, E) is shown as follows: Herbier du Jardin botanique de l'État, Bruxelles, *Gelidium pusillum* (STACKH.) LE JOL. HAUCK, Meeresalg., P. 195 (National Botanical Garden, Brussels).

The explanation of Pl. XLVI, A is shown as follows: "Herb. Lugd. Bat. 40. Austral. No. 947, 192…60 (brownish label), Rhodophyceae, "Herbarium of VICTOR

W. LINDAUER, Algae Novae-Zelandiae Exsiccatae, No. 238, *Gelidium pusillum* LE JOLIS Var. *conchicola* PICC. et GRUN, Piha Auckland 23. 12. 1940" (Rijksherbarium, Leiden).

var. **pulvinatum** FELDMANN
(Plate XLVI, B, C ×ca. 1)

The explanation of the specimen (Pl. XLVI, B) is shown as follows: Herb. WEBER-VAN BOSSE, "Herb. Lugd. Bat. 10 Eur. As. No. 941, 46, 423"; Rhodophyceae, Herb. KÜTZING, *Acrocarpus pulvinatus* KG. Tab. Phyc. XVIII, 37, Willkomm."

The explanation of the specimen (Pl. XLVI, C) is shown as follows: "Herb. WEBER-VAN BOSSE, "Herb. Lugd. Bat. 10 Eur. As. No. 941, 313…742." Rhodophyceae, Herbier J. FELDMANN, Algues, marines, Aust. 1927, J. FELDMANN. (Rijksherbarium, Leiden).

Gelidium pyramidale GARDNER
(Plate XLVI, D ×ca. 1)

The specimen is preserved in British Museum (Natural History), London.

Gelidium rigidiusculum GREVILLE
(Plate XLVI, E ×ca. 1)

This specimen is covered in the envelope noted "Ceylon Algae-W. Ferguson corn 12, 1888, 1–410 Ceylon; 411–443 Tuticorin S. India No. 92" (Royal Botanic Garden, Edinburgh).

Gelidium seminudum J. AGARDH
(Plate XLVII ×ca. $\frac{5}{6}$)

There are specimen from No. 33201 to No. 33213. The specimen of No. 33204 is belonging to BINDER's. There is a sign "ad Liman in Ocean. Pacifico".

The frond is rigid cartilaginous, thick, large and sparsely branched. It is reddish purple in colour and does not adhere to paper in drying (Botanical Museum, Lund).

Gelidium serrulatum J. AGARDH
(Plate XLVIII ×ca. $\frac{1}{2}$)

The specimen is signed "Guayra, Puerto Caribae, Venezuelae". The frond is rigid cartilaginous. The unarticulated species of Corallinaceae and *Chaetomorpha spiralis* OKAM. are attaching on the thick axes of the frond. It does not adhere to paper in drying (Botanical Museum, Lund).

Gelidium sesquipedale THURET
(Plate XLIX ×ca. 4/5)

The frond is rigid membranaceous, compressed, reddish brown in colour. It does not adhere to paper in drying (National Museum of Natural History, Paris).

Gelidium setaceum KÜTZING
(Plate L, A ×ca. 1)

The sign "*Gelidium corneum* Var. *Setaceum* LENORM. in herb and *Sphaerococcus Corneus* Var. *Setaceum* AG." is noted on the left lower part of the specimen. The explanation of the specimen is shown as follows: Herb. WEBER-VAN-BOSSE; "Herb. Lugd. Bat. 10, Eur. As. No." Rhodophyceae, Herb. KÜTZING; *Gelidium Setaceum* KG. Tab. Phyc. XVIII, 54, St. Malo: LENORMAND (Rijksherbarium, Leiden).

Gelidium sonderi KÜTZING
(Plate L, B ×ca. 1)

The explanation of the specimen is shown as follows: Herb. WEBER-VAN BOSSE, "Herb. Lugd. Bat. 10. Eur. As., No. 941, 46…143", Rhodophyceae Herb. KÜTZ; "*G. polycladum* SONDERI, Nagasaki (Nei Kg. Tab. Phyc. XVIII, 55) Tab. Phyc. XIX 24, *Gelidium Sonderi* KG. 1871), No. 3" (Rijksherbarium, Leiden).

Gelidium sonorense DAWSON
(Pl. L, C ×ca. 1)

The explanation of the specimen is shown as follows: "Herb. Lugd. Bat. 50 Amer. Sept. No. 955, 62…25." Rhodophyceae, Smithsonian Institution from the United States of National Herbarium, *Gelidium sonorense* DAWSON, sp. nov. Isotype, Mexico; On reef at Bahia San Francisquito, Near Caaymas, Sonora; E. YALE DAWSON 3551 November 20, 1946 (Rijksherbarium, Leiden).

Gelidium sparsifolium KÜTZING
(Plate L, D ×ca. 1)

There is a sign "Wellington, New Zealand" on the right lower corner of the specimen. The explanation is shown as follows: Herb. WEBER-VAN BOSSE, "Herb. Lugd. Bat. 40. Austral. No. 941, 11…101". Rhodophyceae, Herb. KUETZING (Rijksherbarium, Leiden).

Gelidium spathulatum (KÜTZING) BORNET
(Plate LI, A ×ca. 1)

The explanation of this specimen is shown as follows: "Type ! van *Acrocarpus*

spathulatus Kg. en *G. spathulatum* (Kütz.) Born. Herb. Lugd. Bat. No. 941, 46…77 (Rijksherbarium, Leiden).

Gelidium spinulosum J. Agardh

(Plate LI, B ×ca. 1)

There are specimens from No. 33243 to No. 33252. The frond is rigid, cartilaginous, fine, compressed, brown or reddish purple in colour and does not adhere to paper in drying. The frond is issuing many spinous branchlets on whole part of it. The frond (No. 33243) is issuing tufted branchlets densely (Botanical Museum, Lund).

var. oxyacanthum J. Agardh

(Plate LI, C, LII, A ×ca. 1)

There are specimens from No. 33253 to 33261. The frond is brownish and reddish purple and does not adhere to paper in drying.

The frond of No. 33258 (Pl. LI, C) is fine, issuing spinous branchlets. They are aggregated in tufts on the upper part of the frond. It is greenish brown in colour.

The frond of No. 33260 (Pl. LII, A) is fine, rigid, branched densely in tufts in the upper part of it. It does not adhere to paper in drying (Botanical Museum, Lund).

Gelidium supradecompositum Kützing

(Plate LII, B ×ca. 1)

The pinkish label noted No. 3 "Type" is attached on the specimen. The explanation of this specimen is shown as follows: Herb. Weber van Bosse, "Herb. Lugd. Bat. 60 Amer. Merid. No. 941, 45…50", Rhodophyceae Herb. Kuetzing; *Gelidium supradecompositum* Kg. Tab. Phyc. XVIII, 54; Rio Janeiro, Hagendorf ? (Rijksherbarium, Leiden).

Gelidium torulosum Kützing

(Plate LII, C ×ca. 1)

The reddish paper "Type van *Gelidium torulosum* Kg." is attached on this specimen. The explanation of the specimen is shown as follows: Herb. Weber van Bosse. "Herb. Lugd. Bat. 60 Amer. Merid. No. 941, 45…43, Rhodophyceae, Herbarium Kuetzing (Rijksherbarium, Leiden).

Index of the species

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Gelidium arbusculum Börg. .... P. 510, Pl. II, B slightly reduced
Gelidium asperulum Kütz. .... P. 510, Pl. II, C slightly reduced
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Gelidium aureum Ag. .... P. 510, Pl. III, B ×ca. 1
Gelidium australe J. Ag. .... P. 511, Pl. IV ×ca. 2/3
Gelidium biserratum Börg. .... P. 511, Pl. V ×ca. 1
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var. *pulchellum* Grev. .... P. 513, Pl. XVII, A ×ca. 1
var. *pulvinatum* Ag. .... P. 513, Pl. XVII, B ×ca. 1
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Gelidium foliosum Dang. .... P. 516, Pl. XXIV, C slightly reduced
Gelidium harveyanum Grev. .... P. 516, Pl. XXV, A, B ×ca. 1
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Gelidium hildebrandtii (Hauck) Schm. .... P. 516, Pl. XXVII slightly reduced
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Gelidium latifolium Börg. .... P. 517, Pl. XXVIII, B ×ca. 1; XXIX slightly reduced; XXX, XXXI, A, B, C, XXXII, A ×ca. 1
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Gelidium lingulatum J. Ag. .... P. 517, Pl. XXXII, C, XXXIII, A, B ×ca. 1
Gelidium linoides Kütz. .... P. 517, Pl. XXXIII, C ×ca. 1
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Gelidium serrulatum J. AG. .... P. 521, Pl. XLVIII × ca. ½
Gelidium sesquipedale THUR. .... P. 522, Pl. LVIX × ca. 4/5
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Gelidium sonderi KÜTZ. .... P. 522, Pl. L, B × ca. 1
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Gelidium sparsifolium. KÜTZ. .... P. 522, Pl. L, D × ca. 1
Gelidium spathulatum (KÜTZ.) BORN. .... P. 522, Pl. LI, A × ca. 1
Gelidium spinulosum J. AG. .... P. 523, Pl. LI, B × ca. 1
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Gelidium supradecompositum KÜTZ. .... P. 523, Pl. LII, B × ca. 1
Gelidium torulosum KÜTZ. .... P. 523, Pl. LII, C × ca. 1

Plate I

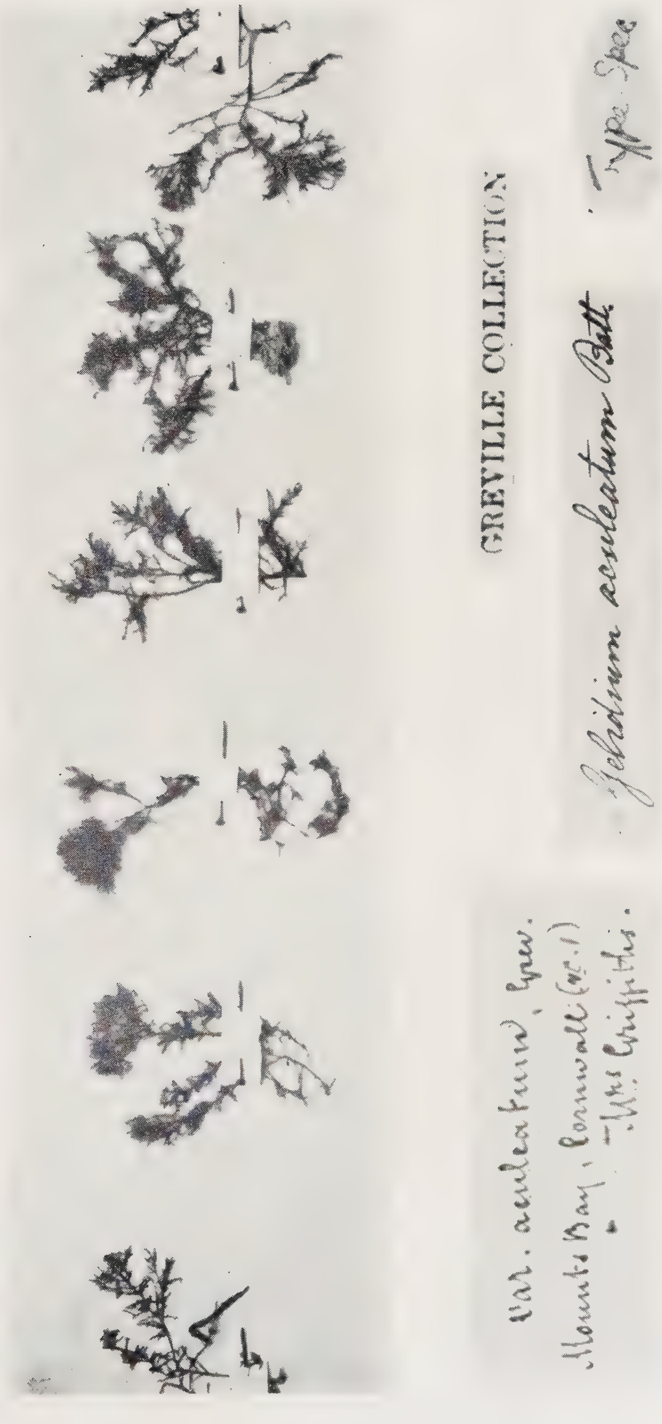


Plate II

A

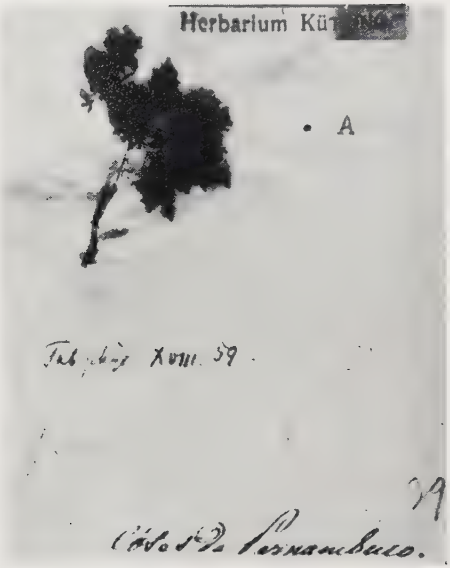
B

Plate IV

Plate V

Plate VI

Plate VIII


A

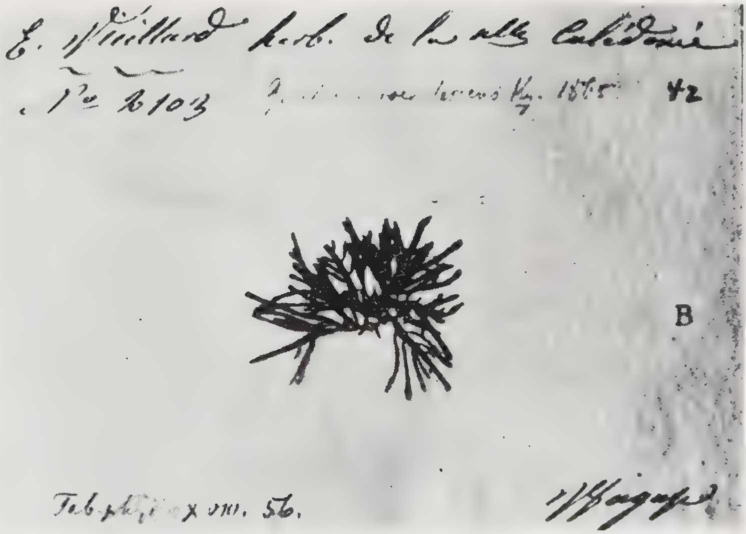

B

Plate X

A
Sebastopol.
11 Décembre 1889
Herb. G. THURET

B

Plate XII

HERB. G. THURET
HARVEY — Australian Algæ

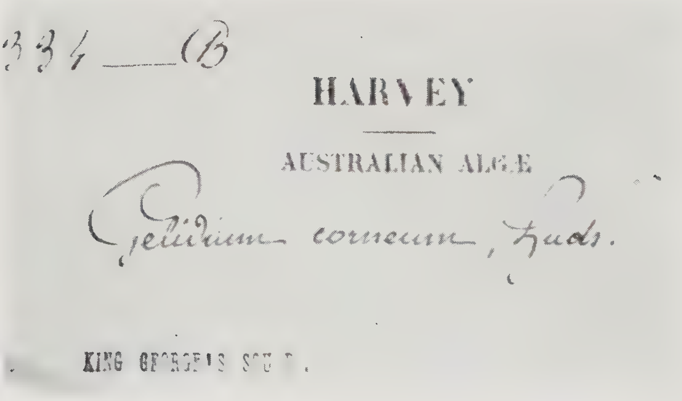

334 — B
HARVEY
AUSTRALIAN ALGÆ
Gelidium corneum, Huds.

Plate XIV

Plate XV

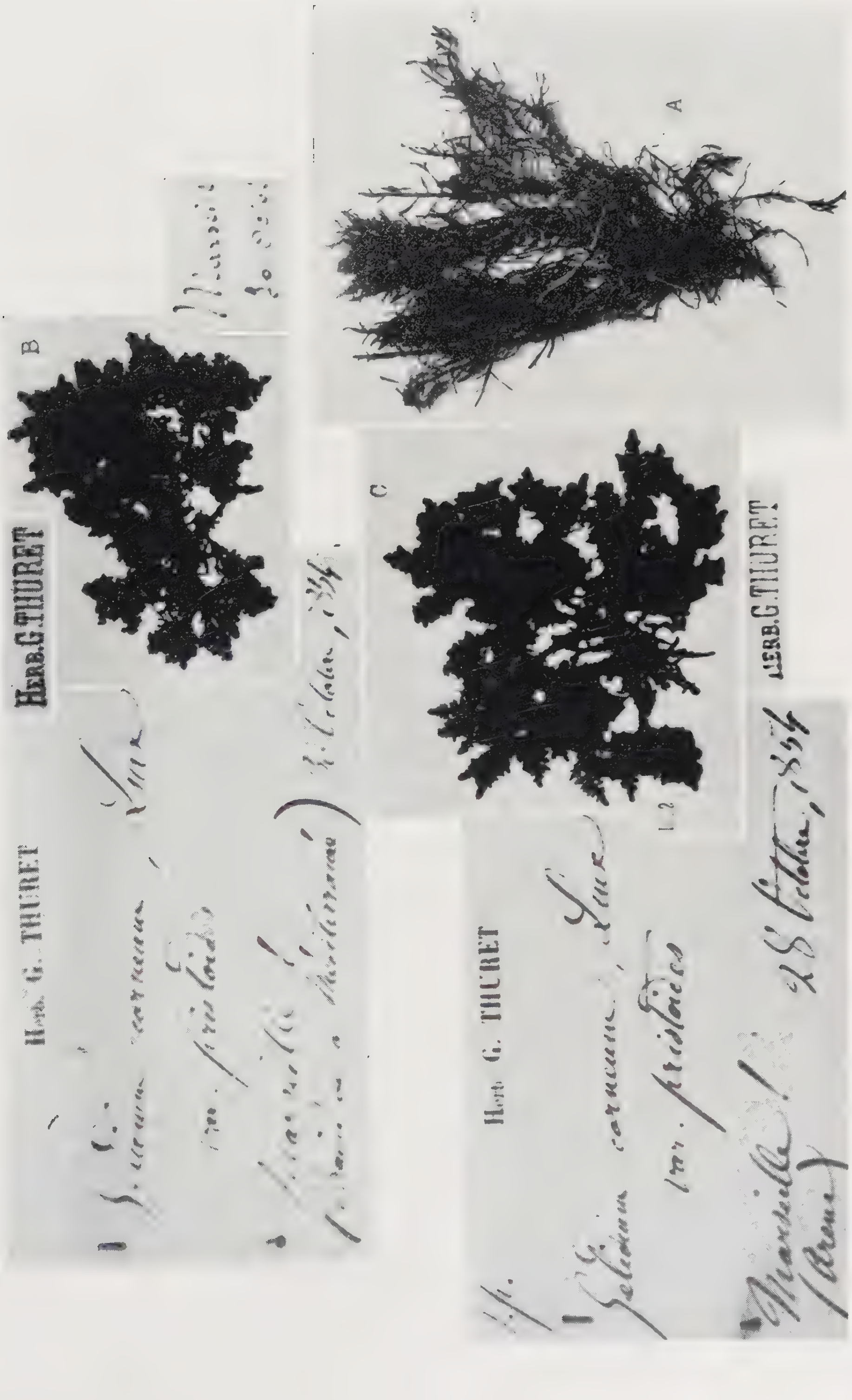


Plate XVI

Plate XVII

Plate XVIII

Plate XX

A

B

Plate XXI

Plate XXII

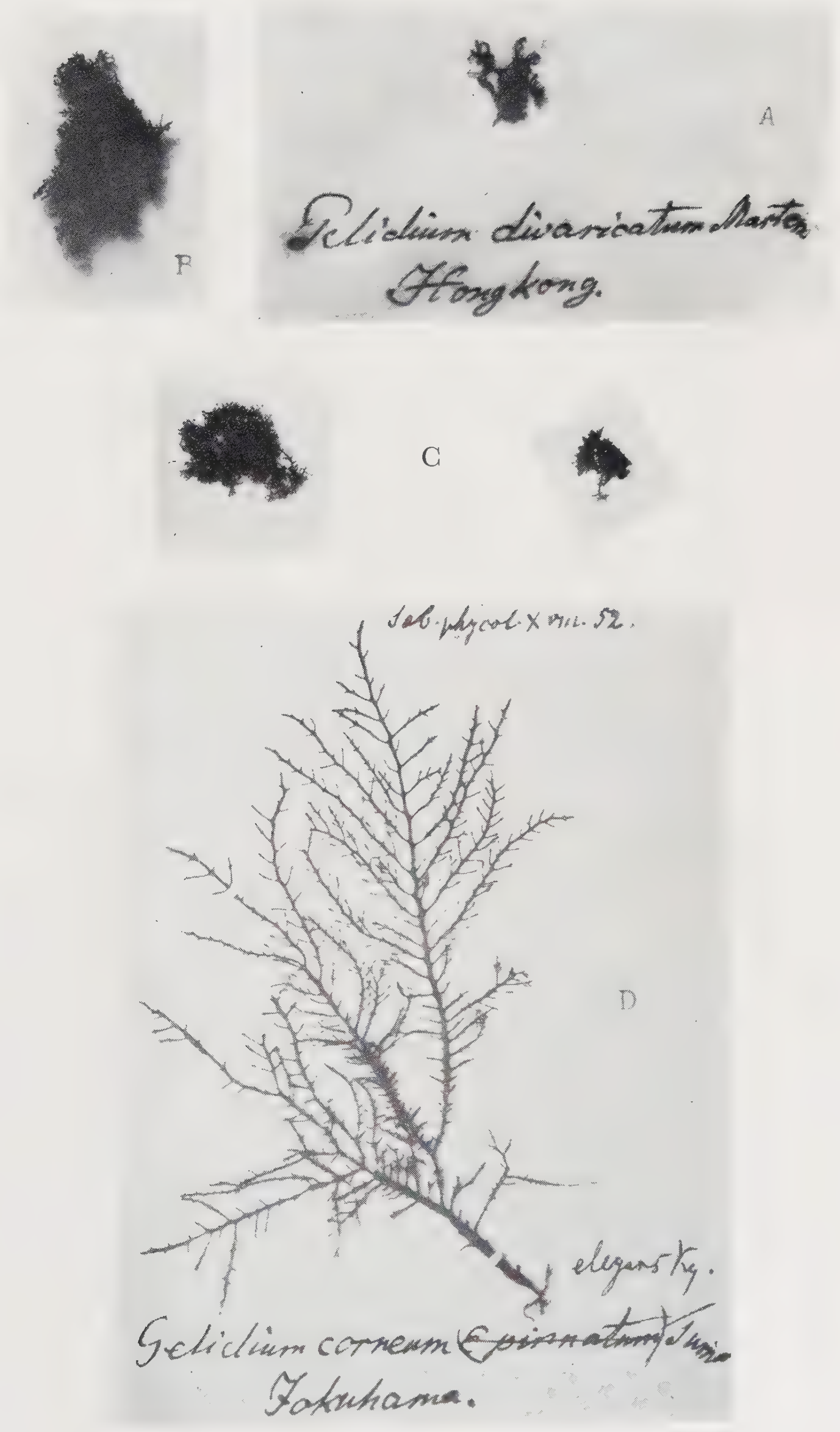

A
B
Gelidium divaricatum Martens
Hongkong.
C
Tab. phycol. XVIII. 52.
D
elegans Kg.
Gelidium corneum pinnatum Turn.
Jokuhama.

Plate XXIV

A
B
C
ALGUES MARINES
recueillies par P. DANGEARD
Gelidium flaccidum P. Dang.
Le Botaniste, XXXV, 1951, p. 23
Localité : Dakar, Bel Air
ALGUES MARINES
recueillies par P. DANGEARD
Nom Gelidium foliosum P. Dang.
Le Botaniste, XXXV, 1951, p. 22
Localité : Dakar.

Plate XXV

A
CEYLON ALGÆ — W. FERGUSON. Com. 12.1888.
ROYAL BOTANIC GARDEN
HERBARIUM
EDINBURGH
CEYLON ALGÆ — W. FERGUSON. Com. 12.1888.
1-410 Ceylon; 411-448 Tuticorin, S. India.
No. 57. 58, 58a 59, 60.
601
B
Gelidium Harveyanum, Gr.

Plate XXVI

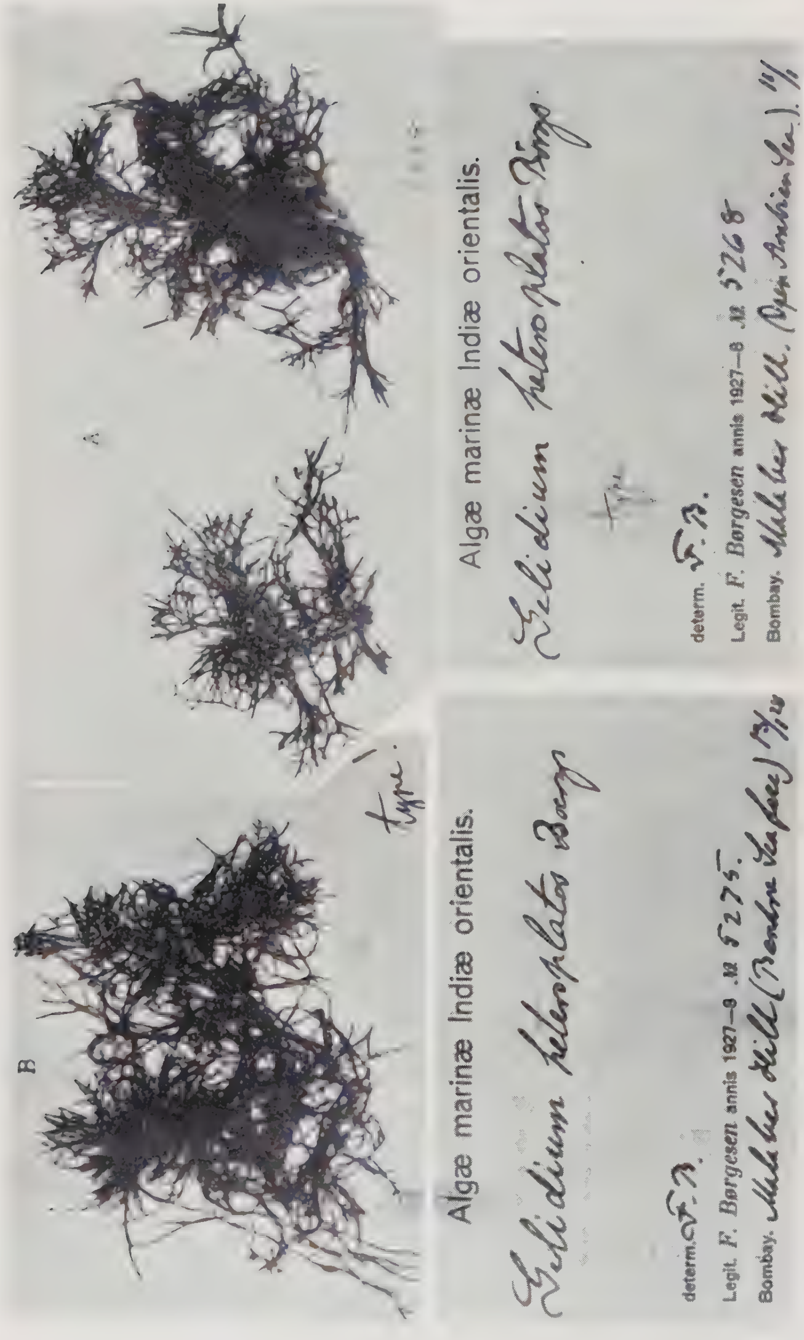
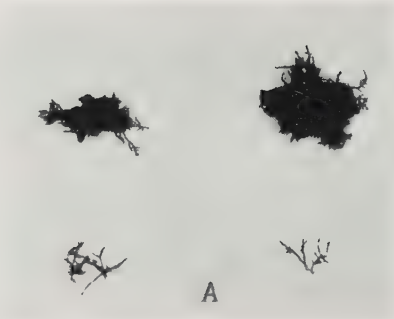
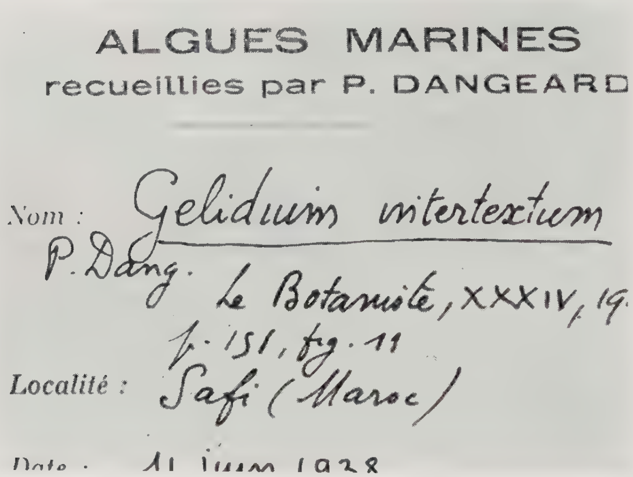

A
B
Algæ marinæ Indiæ orientalis.
determ.
Legit. F. Børgesen annis 1927—8 № 5268
Bombay.
Algæ marinæ Indiæ orientalis.
determ.
Legit. F. Børgesen annis 1927—8 №
Bombay.

Plate XXVII




ALGUES MARINES
recueillies par P. DANGEARD

Nom : Gelidium intertextum P. Dang. Le Botaniste, XXXIV, 19. p. 151, fig. 11

Localité : Safi (Maroc)

Date : 11 juin 1938

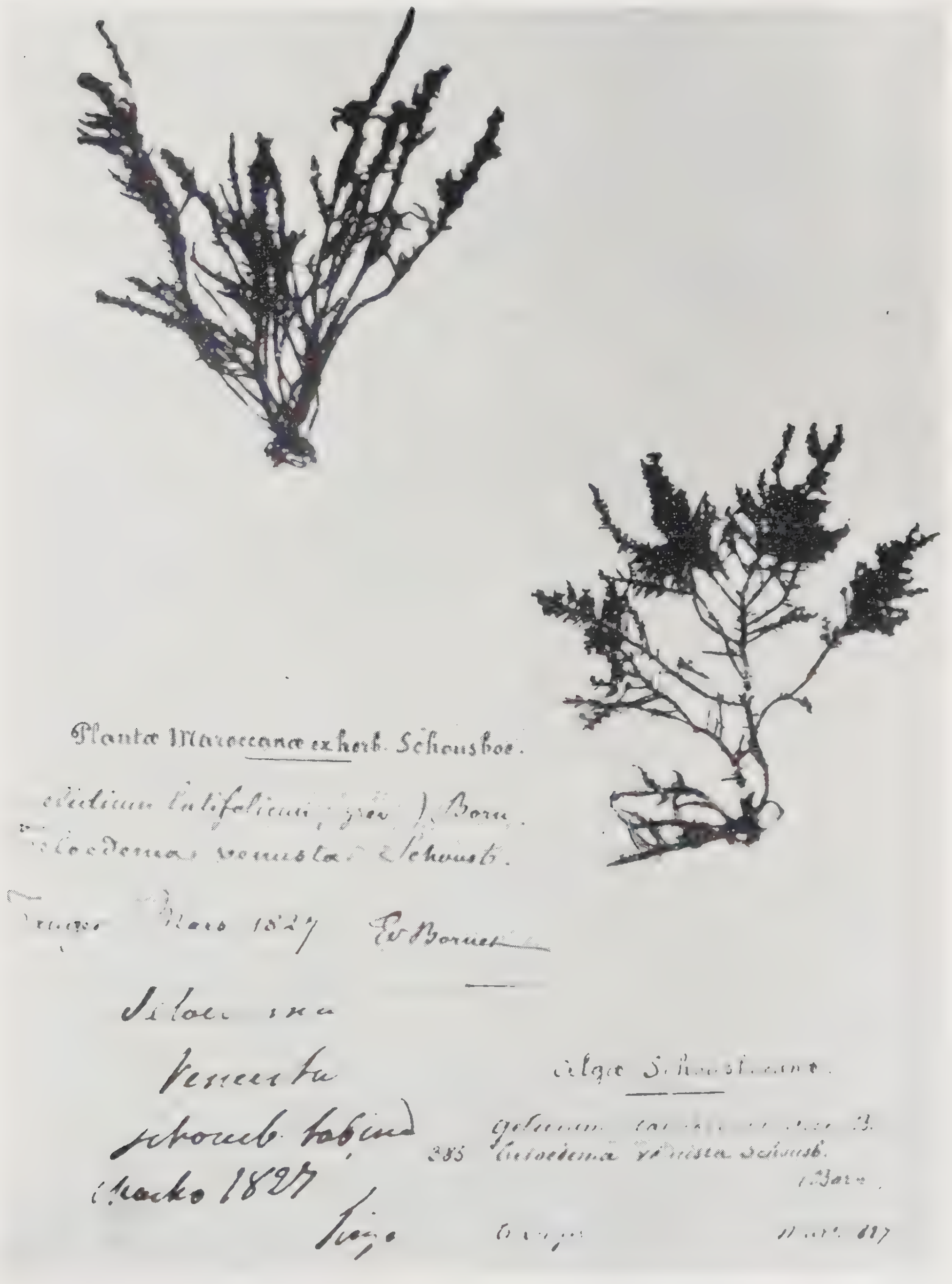
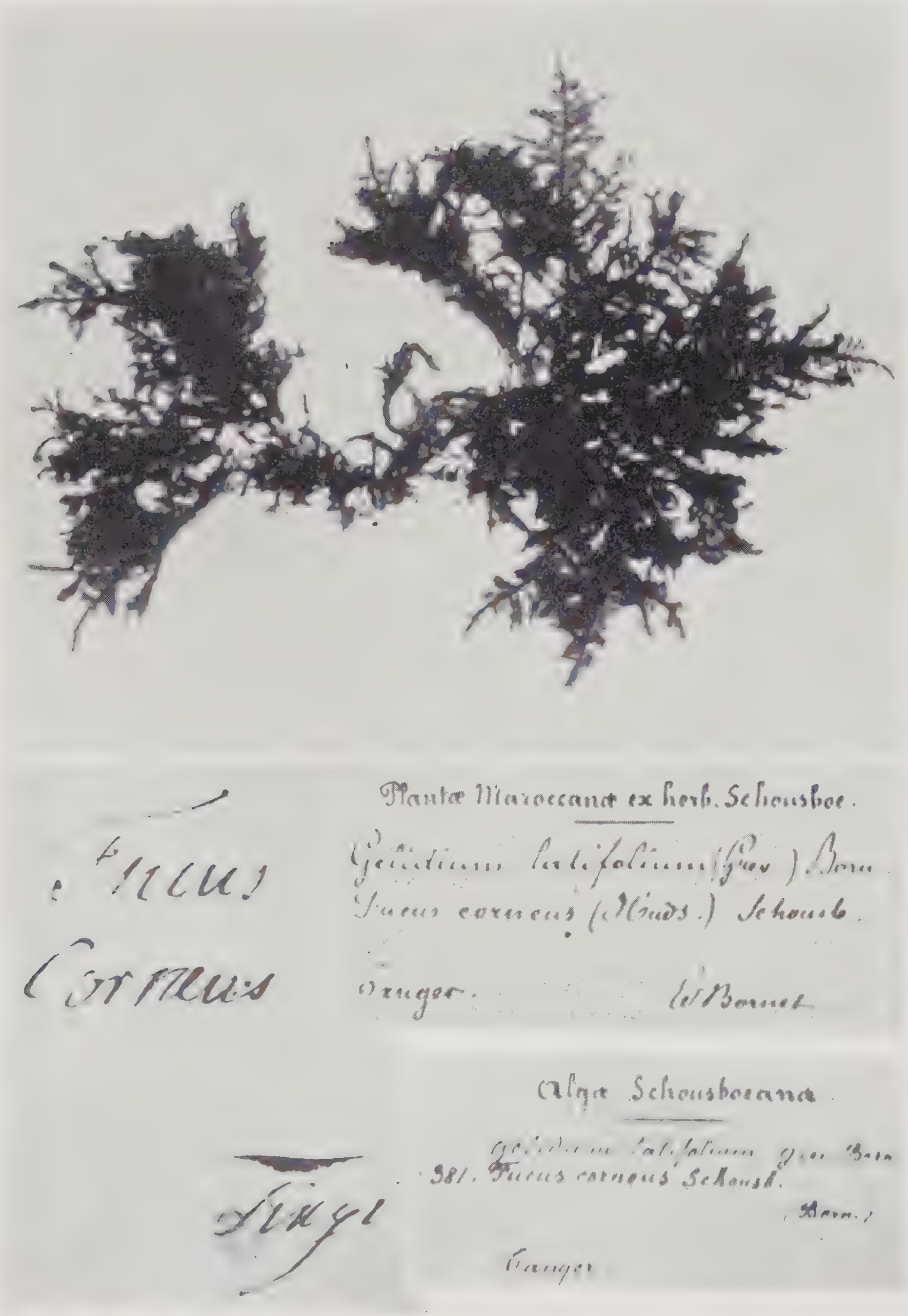
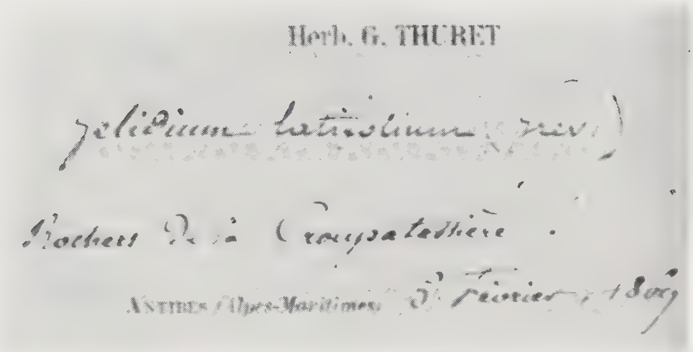
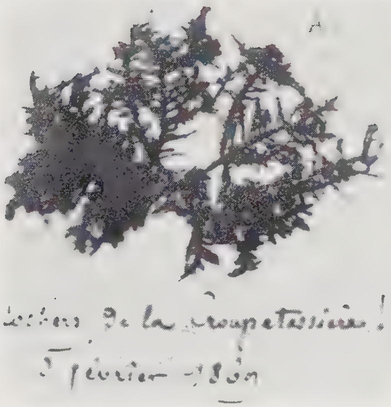

Plantæ Maroccanæ ex herb. Schousboe.

Plate XXX


Plantæ Maroccanæ ex herb. Schousboe.
Gelidium latifolium (Grev.) Born.
Fucus corneus (Huds.) Schousb.
Alga Schousboeana
381. Fucus corneus Schousb.


Herb. G. THURET
Antibes (Alpes-Maritimes)


A

Herb. G THURET
B

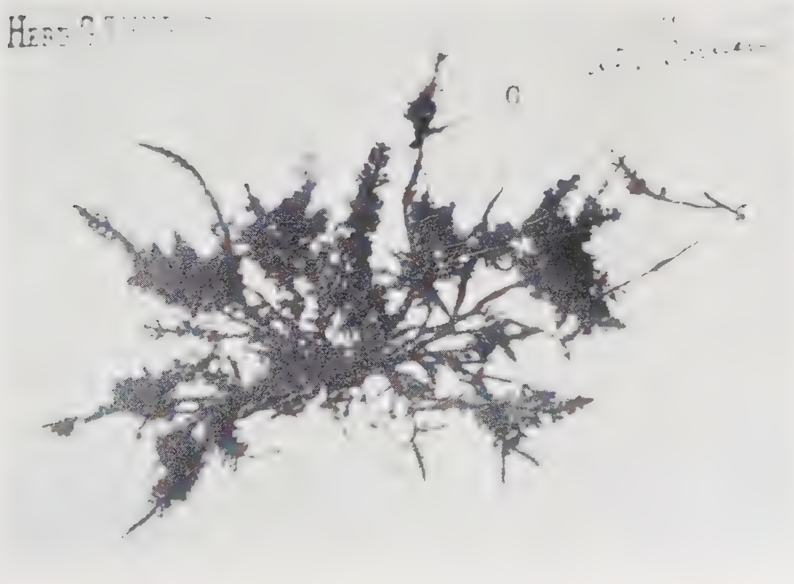
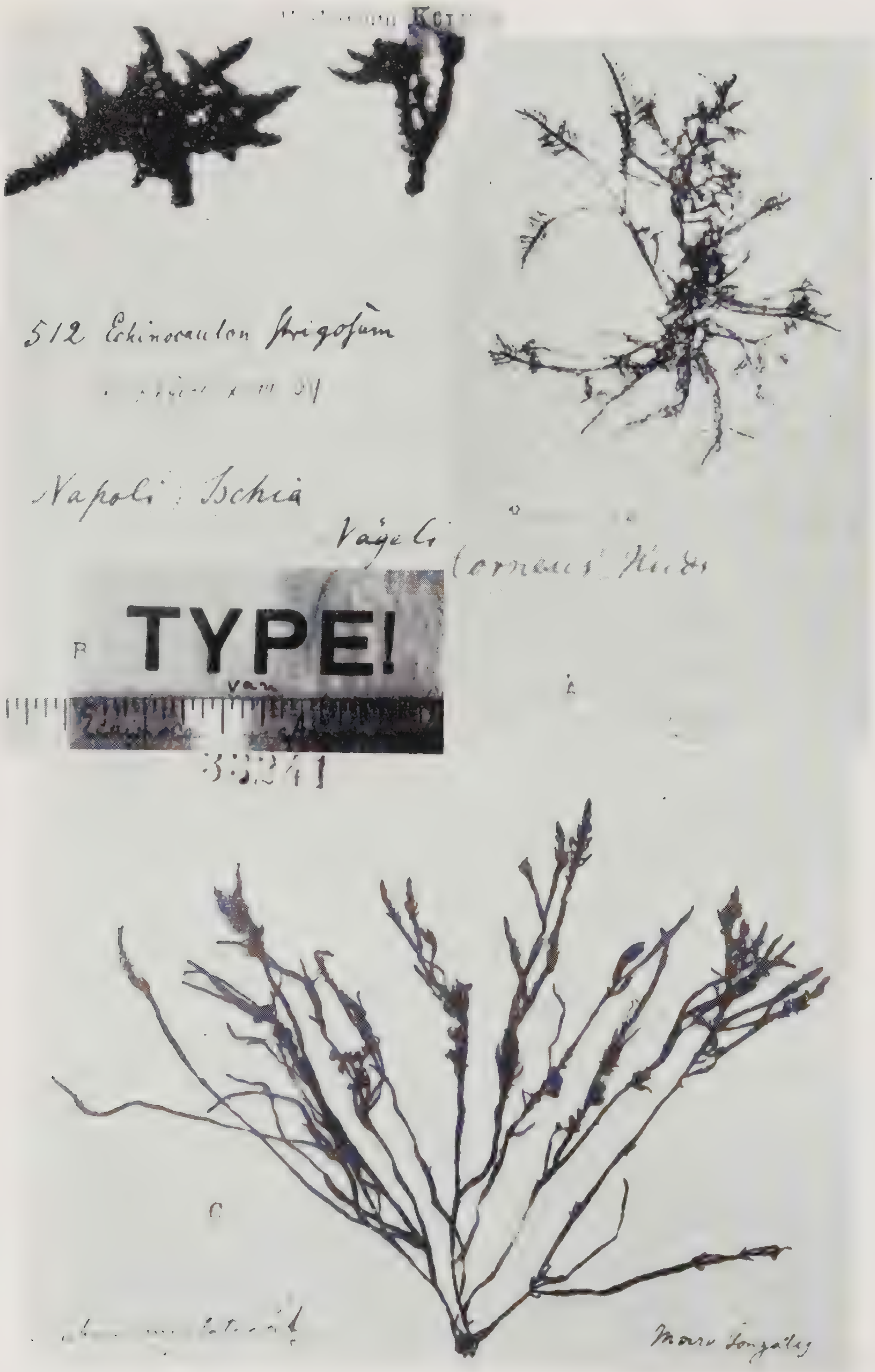

C

Plate XXXII



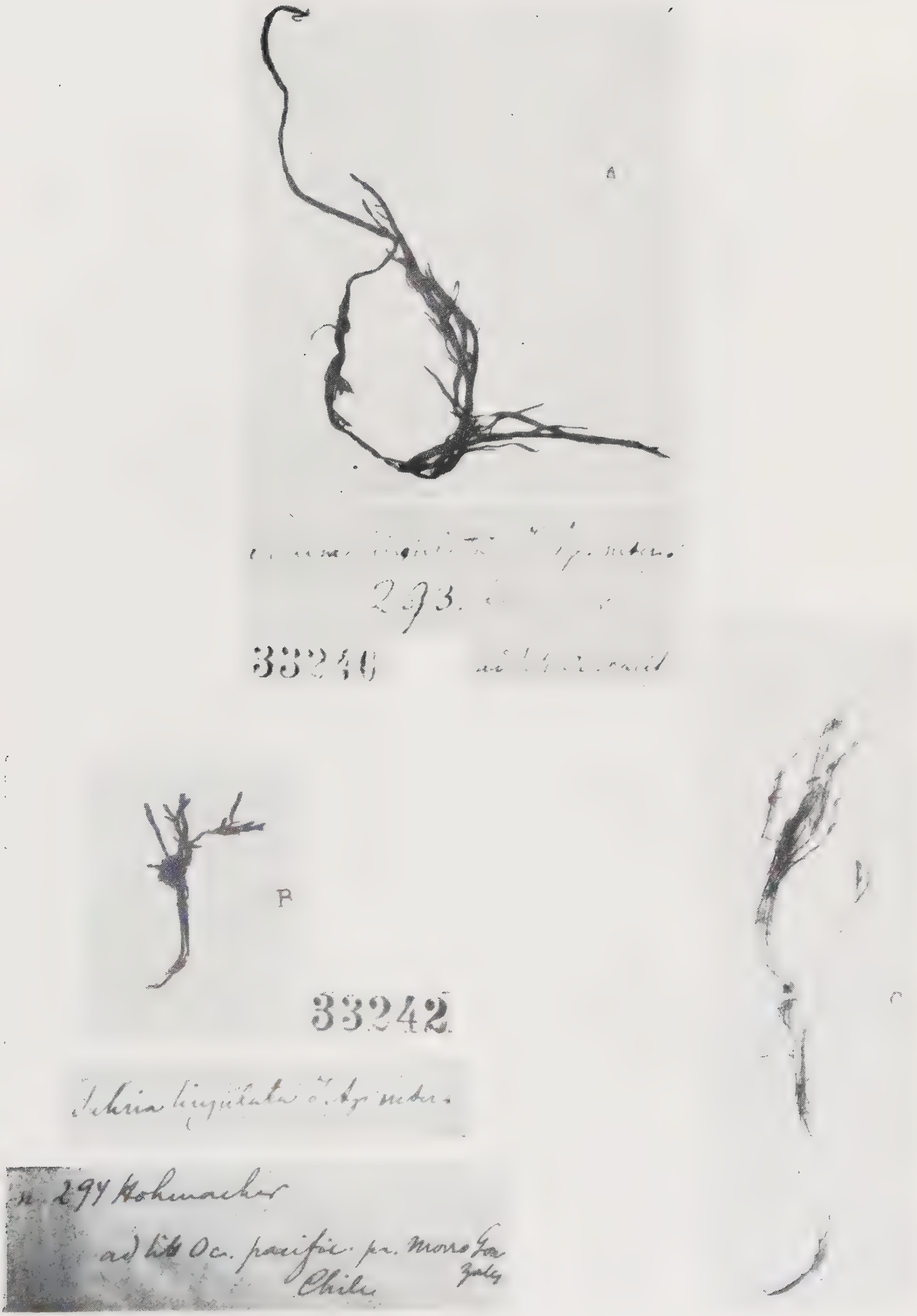

A
293.
33246
B
33242
n. 294 Hohenacker
Chile
C

Plate XXXIV

Plate XXXV

Plate XXXVI

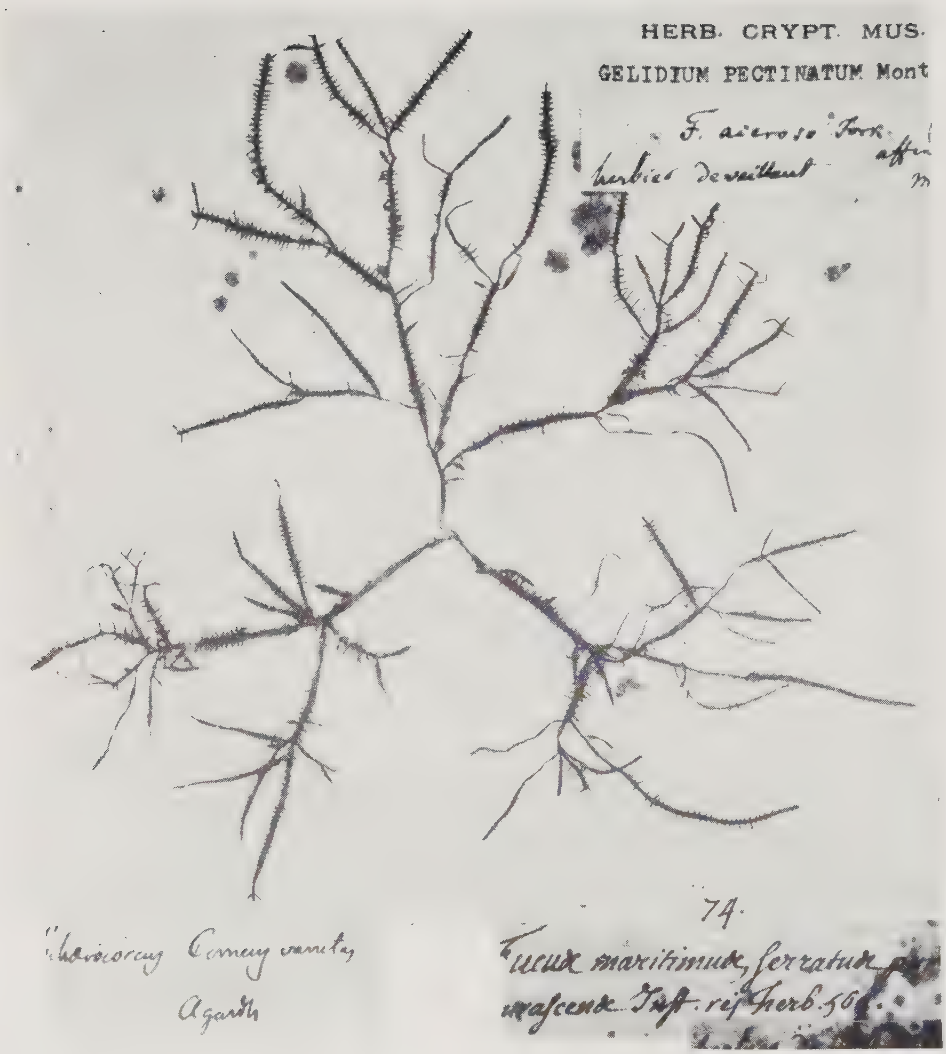


Plate XXXVII

Plate XXXVIII

Plate XXXIX

Plate XL

Plate XLI

Herb. Wight. propr.
Cryptogamia
GREVILLE COLLECTION
Peninsula Ind. orientalis.

Plate XLII

Plate XLIII

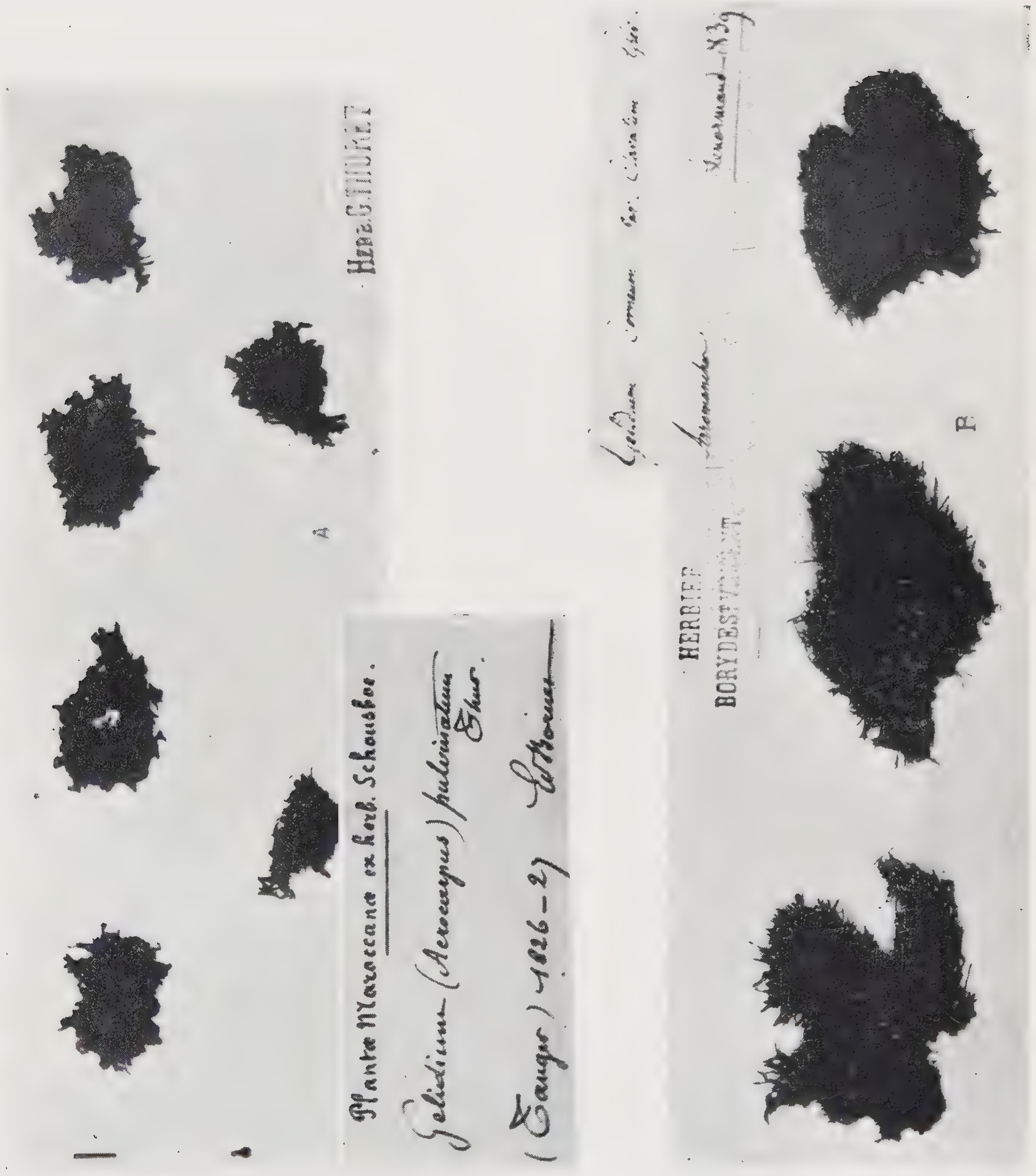

HERB. G. THURET
A
Plantae Maroccanae ex herb. Schousboe.
Gelidium (Acrocarpus) pulvinatum Thur.
B

Plate XLIV

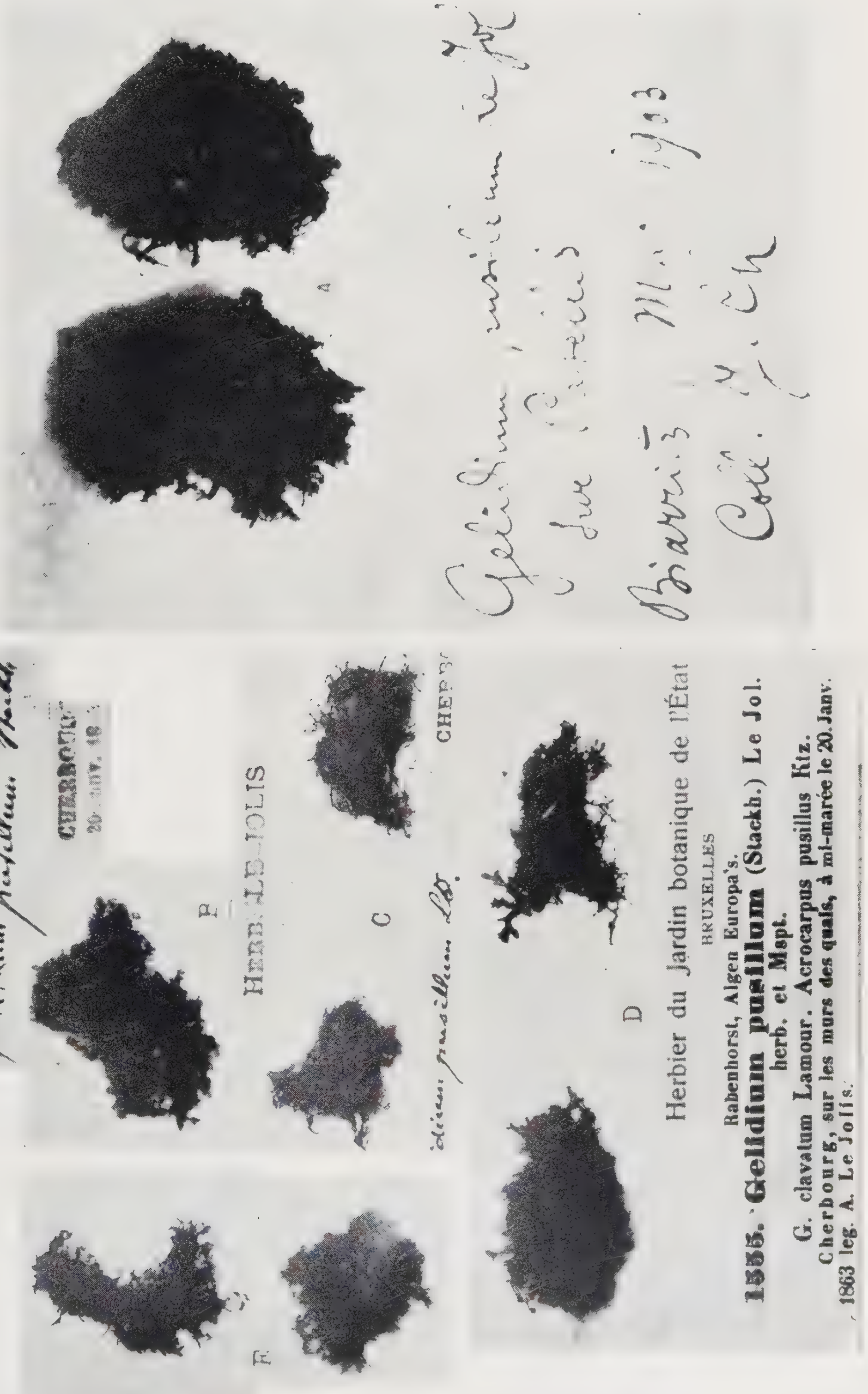

A
B
HERB. LE JOLIS
C
CHERB
D
E
Herbier du Jardin botanique de l'État
BRUXELLES
Rabenhorst, Algen Europa's.
1555. Gelidium pusillum (Stackh.) Le Jol. herb. et Mspt.
G. clavatum Lamour. Acrocarpus pusillus Ktz.
Cherbourg, sur les murs des quais, à mi-marée le 20. Janv. 1863 leg. A. Le Jolis.

Plate XLVI

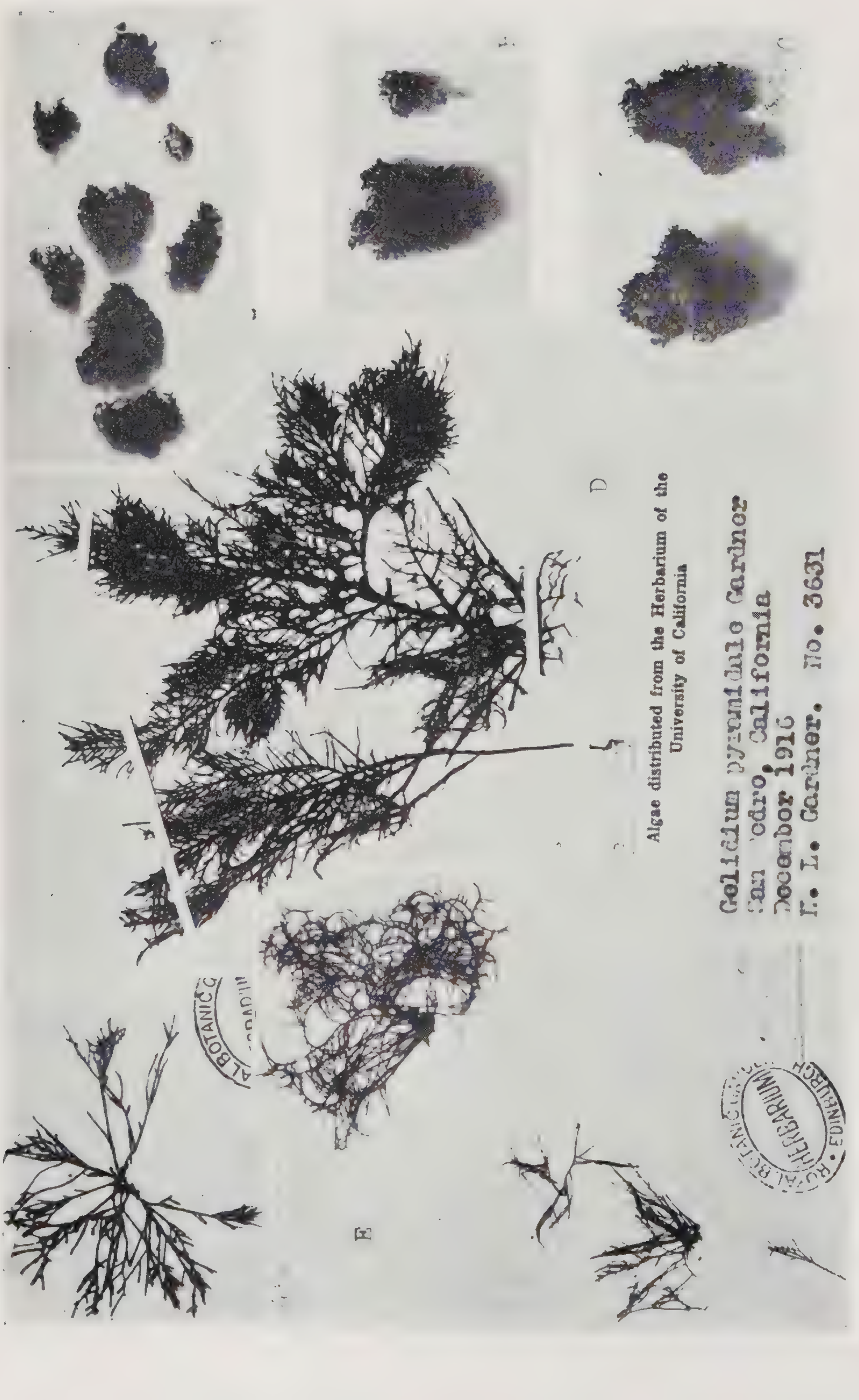

D
E
Algae distributed from the Herbarium of the University of California
San Pedro, California
December 1916
N. L. Gardner. No. 3631

Plate XLIX

Plate L

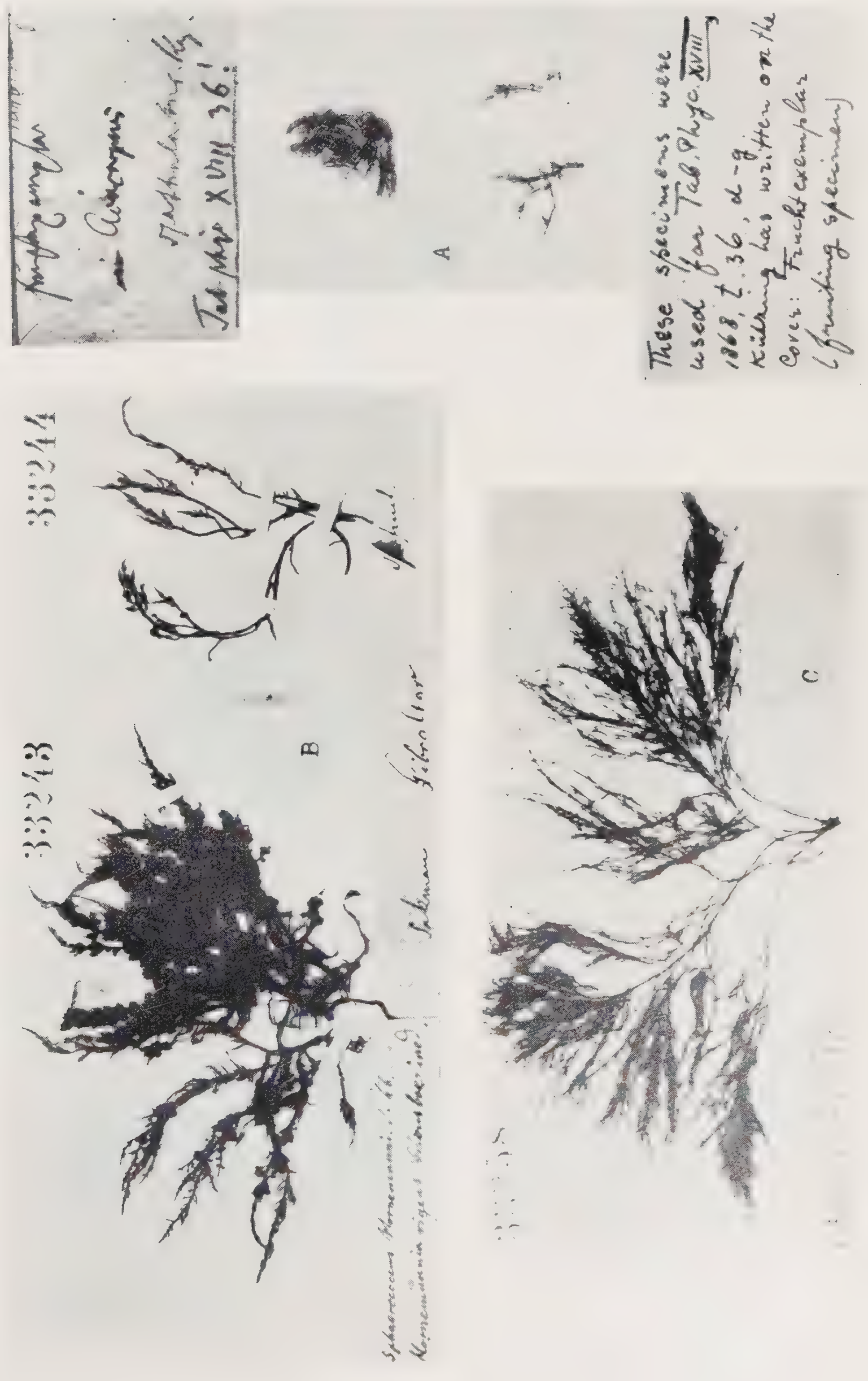

A
B
C
33243
33244
Tab. phyc. XVIII 36!
These specimens were used for Tab. Phyc. XVIII, 1868, t. 36, d-g. Kützing has written on the cover: Fruchtexemplar (fruiting specimen)
Gibraltar

Plate LII

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